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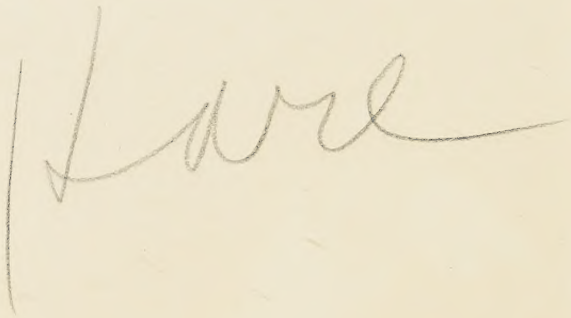

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REFRACTION OF THE EYE

BY

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PREFACE

THE contents of this small volume on "Refraction" are based on the needs of the student who wishes to take up the study of this important branch of ophthalmology. It is evident that this cannot be accomplished without the application of these principles to actual cases.

The chapter on Optics is elementary, but enough is given to permit of an intelligent understanding of the second chapter, in which are considered the optical principles as applied to the eye.

In Chapter III the instruments necessary for proper refraction are considered together, in order that their interdependence may be at once manifest.

As the beginner is especially liable to overlook the great importance of a careful history of each case of refraction, it has been thought desirable to devote an entire chapter to this part of the subject. In Chapter IV will be found the various asthenopic symptoms and their meaning.

Each variety of ametropia is considered in a separate chapter. There is also a chapter devoted to the muscle insufficiencies and another to strabismus. In the chapter on Muscle Insufficiencies the practice of promiscuous muscle-cutting is condemned, and in its stead is advocated an exact search for cause of muscle imbalance, which, if relieved, will correct the muscle error in nearly all cases without resort to muscle-cutting or the constant use of prisms. In the chapter on Strabismus Worth's plea for the early treatment of squint is reiterated, and his method of fusion training is briefly described.

In Chapter XIV the astigmatic axis in relation to nasal obstruction is considered. It is a clinical certainty that proper treatment of the nose, in many cases, relieves many of our most obstinate cases of refraction.

In Chapter XV the author has given cases taken from his own private records, which exemplify the text. In studying the various forms of ametropia it is recommended that reference be made to these cases.

In Chapter XVI are briefly considered the measurements necessary for the proper adjustment of eye-glasses and spectacles for the benefit of ophthalmologists whose prescriptions are of necessity filled by some distant optician.

H. C. P.

320 N. Meridian St., Indianapolis, Indiana,
August, 1908.

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Refraction of the Eye

CHAPTER I

OPTICS

Light is that form of energy which, acting upon the organs of sight, renders visible the objects from which it proceeds. Light is distributed from a luminous point in every direction and in every plane in straight lines. These lines of direction are called *rays*. The rapidity with which the rays travel is governed by the density of the medium through which they pass, a dense medium retarding the rays, and a rare medium accelerating the rays.

Rays of light diverge from the point of luminosity, and the degree of divergence is in inverse proportion to the distance from which they come—*i. e.*, the nearer the source of light, the greater the divergence.

For our purpose rays of light which enter the eyes from a distance of 6 meters may be considered parallel. As a matter of fact, such rays entering the normal eye have a divergence of but 4/6000, which may be safely considered insignificant.

Rays of light meeting a body are reflected or absorbed, or if the body is transparent, they pass through the body and are refracted.

Reflection occurs from any polished surface, and takes place according to two laws: (1) The reflected rays—those which rebound from a polished surface (R), and the incident rays—those which strike the surface of an object (I), are in the same plane, which plane is perpendicular to the reflecting

surface. (2) The angle of reflection is equal to the angle of incidence (Fig. 1).

An example of this is seen when reflection takes place from a plane mirror: the image is projected backward to a distance behind the mirror equal to the distance of the object in front of it, the image being of the same size as the object (Fig. 2, I).

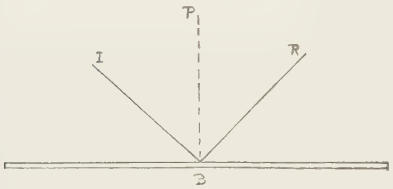


Fig. 1.—*I*, Incident ray; *R*, reflected ray.

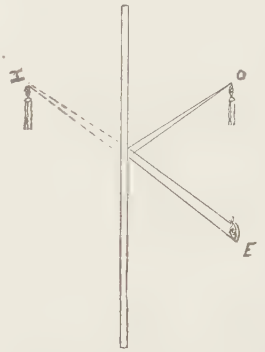


Fig. 2.—*O*, The candle; *E*, the eye of the observer; *I*, the virtual image of the candle.

This image formed by a plane mirror is called the *virtual image.*

Reflection from a concave surface varies from that of a plane surface in that in the former parallel rays are reflected as con-

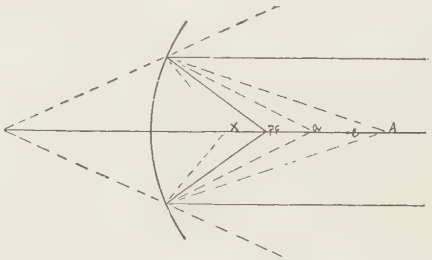


Fig. 3.—Reflection from a concave surface: *PF*, Principal focus; *C*, optical center.

vergent rays which meet on the axis at a point called the principal focus (Fig. 3, P F). This principal focus is midway between the mirror and the optical center (C), and the distance from

the mirror to the principal focus is called the focal length of the mirror.

The reverse of this is true: if the luminous point is at P F, the reflected rays will be reflected parallel to each other and to the axis of the mirror. If the object is placed beyond the principal focus at A, the reflected rays will focus between the center and the principal focus at a. The reverse of this is true, in that if the object is between the principal focus and the center at a, the focus of this will be beyond the center at A. These two points, A and a, bear a reciprocal relation to each other and are called *conjugate foci.* It naturally follows from this that if the object is placed nearer the mirror than the principal focus (X), the reflected rays will be divergent.

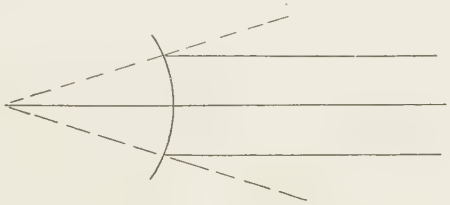


Fig. 4.—Reflection from a convex surface.

Concave mirrors produce several kinds of images: an enlarged erect *virtual image* if the object is placed nearer than the principal focus; an enlarged, inverted *real image* if the object is placed between the principal focus and the center; an inverted image of the same size when the object is placed at the center; a smaller inverted real image if the object is placed beyond the center; and no image of an object if placed at the principal focus.

Reflection from a Convex Surface.—Parallel rays of light falling on a convex surface are reflected as divergent rays (Fig. 4). The foci of convex mirrors are, therefore, virtual, and the image, whatever the position of the object, is erect and smaller than the object.

Refraction.—A ray of light passing from one transparent medium to another is deflected or refracted unless the ray falls

perpendicular to the surface separating the two media, when it continues its course in a straight line (Fig. 5 H). A ray before entering the second medium is called *incident* (a b), and after leaving it, emergent (c d). A ray in passing from a rarer to a denser medium is deflected toward the perpendicular (b c), while a ray passing from a denser to a rarer medium is deflected, or refracted, away from the perpendicular (c d). The angle formed by the incident ray with the perpendicular is called the *angle of incidence;* the angle formed by the emergent or refracted ray with the perpendicular is known as the *angle of refraction.*

The index of refraction is the relative density, or the comparative length of time occupied by light in traveling a definite distance in different transparent media. Air is taken

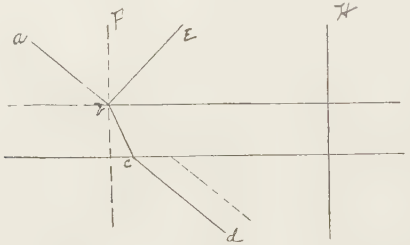


Fig. 5.—Refraction of rays of light.

as the standard, 1.00, water is 1.33, glass is 1.50, the diamond, 2.50, and the cornea the same as water, 1.33. The crystalline lens has an index of refraction of 1.40.

Reflection accompanies refraction, the rays being divided at the point of incidence into a refracted portion (b c) and a reflected portion (b e) (Fig. 5).

Prisms.—A prism is a wedge-shaped piece of glass or other refracting substance contained between two plane surfaces. The plane surfaces incline toward each other and are called the sides. The apex is where the two plane surfaces meet, and the base is the thickest part of the prism. The refracting angle is the angle at which the sides come together (Fig. 6).

The Action of a Prism on Light-rays.—Rays of light passing through a prism are deflected toward its base. If an

incident ray is perpendicular to the surface of a prism, there will be only one refraction, and that occurs at the point of emergence. If an incident ray forms an angle other than a right angle with the first surface of a prism, then it will be refracted twice, *i. e.*, as it enters and as it leaves the prism (Fig. 6).

Prisms do not cause rays of light to diverge or converge, for rays of light which are parallel before refraction by a prism are parallel after refraction (Fig. 6).

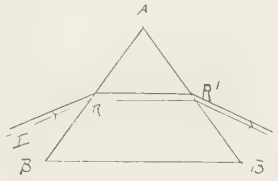


Fig. 6.—A prism: *A*, Apex; *A–B*, sides; *I*, incident ray; *R*, *R'*, refracted rays.

The Position of a Prism.—When a prism is placed before an eye, its position is described by the direction of its base: base up, means the base is toward the brow; base in, means the base is toward the nose; base out, means the base is toward the temple; and base down, means the base is toward the cheek. An object viewed through a prism has the appearance of being

Fig. 7.—Crossed lines for neutralization of prisms.

displaced toward its apex, and prisms are, therefore, used to—(1) Counteract the effects of muscular insufficiency or paralysis; (2) to test the amount of muscular imbalance; (3) to test the extent to which the eyes can be deviated from parallelism; (4) for detecting a simulated blindness; and (5) for the exercise of weak muscles.

Prism Numbers.—Prisms are numbered from 1 to 20 units (usually abbreviated △), each unit being equivalent to about one-half a perimeter or actual degree.

Neutralization of Prisms.—Prisms are neutralized by finding the axis in which they decenter the lens. This is determined by looking through the lens or prism at two lines which cross each other at right angles at their center (Fig. 7), then place prisms of increasing strength, base toward the displacement, until the two lines cross in the optical center of the lens.

LENSES

A lens is a transparent refracting medium, usually made of glass, one or both surfaces of which are curved. They are of two kinds, spheric and cylindric. Of the spheric lenses, there are six varieties:

1. Planoconvex—one surface plane, the other convex (Fig. 8).
2. Biconvex—both surfaces convex (Fig. 9).

Fig. 8.—Planoconvex.

Fig. 9.—Biconvex.

Fig. 10.—Convex meniscus.

3. Concavoconvex, or converging meniscus, which has one surface convex, the other concave, the convex surface having the shorter radius of curvature (Fig. 10).
4. Planoconcave—one surface plane, the other concave (Fig. 11).
5. Biconcave—both surfaces concave (Fig. 12).
6. Concavoconvex, or diverging meniscus, in which the concave surface has the shorter radius of curvature (Fig. 13).

Convex lenses are called plus lenses (+), and concave lenses are called minus lenses (−). A convex spheric lens may be considered as two prisms placed base to base, and a concave

spheric lens as two prisms placed apex to apex. It can thus be seen, as rays of light passing through a prism are deflected toward its base, that a convex spheric lens will converge rays of light (Fig. 14), and a concave spheric lens will diverge rays of light (Fig. 15).

Meniscus or periscopic lenses, whether concave or convex, diminish spheric aberration and materially enlarge the field of

Fig. 11.—Planoconcave.

Fig. 12.—Biconcave.

Fig. 13.—Concave meniscus.

vision. Such lenses are especially valuable in high degrees of hypermetropia or more than one diopter of hypermetropic or compound hypermetropic astigmatism.

A ray which passes through the center of a lens, called the optical center, at right angles to its surface, is not refracted. All other rays undergo more or less refraction. A line which

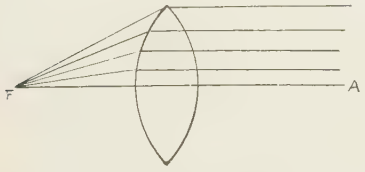


Fig. 14.—Converging power of a convex lens.

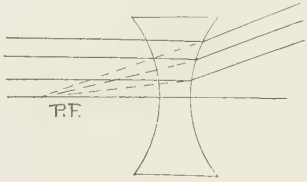


Fig. 15.—Diverging power of a concave lens.

passes through the optical center of a lens at right angles to its surface is termed the principal axis of a lens (A F, Fig. 14).

The Focus of Convex Lenses.—The point at which rays of light converge after passing through a convex lens is called the focus, the principal focus being the focus for parallel rays; and the distance of this point from the optical center of the lens is called the focal length of the lens. It can thus be seen

that rays emanating from an object placed at the principal focus will emerge as parallel rays after passing through the lens (Fig. 14).

Divergent rays emanating from a point outside the principal focus meet at a distance beyond the principal focus on the opposite side of the lens, and if the distance of the luminous point is equal to twice the focal length of the lens, the rays will

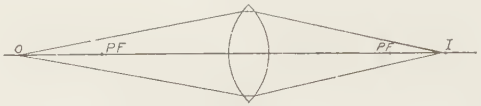


Fig. 16.—Conjugate foci of a convex lens (*O* and *I*): *PF*, Principal focus.

focus at a point the same distance beyond the lens (Fig. 16). It is also true that rays emanating from this point beyond the lens would come to a focus in front of the lens twice the distance of the focal length. For this reason these points are conjugate foci, which are interchangeable foci, in which the image can be replaced by the object and the object by the image (Fig. 16).

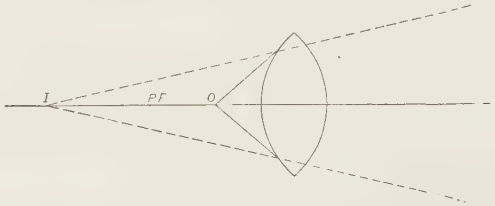


Fig. 17.—Virtual image of a convex lens: *O*, Object; *I*, virtual image; *PF*, principal focus.

If the rays of light diverge from a point between the principal focus and the lens, the rays of light will issue from the lens divergent, though less divergent than before entering. If they are prolonged backward, they will meet at a point further from the lens than the original luminous point, and this will be the virtual or negative focus (Fig. 17).

Biconvex lenses, therefore, have two principal foci—one on either side at equal distance from the center. In ordinary lenses, and those in which the radii of the two surfaces are

nearly equal, the principal focus practically coincides with the center of curvature.

The Focus of Concave Lenses.—The focus of concave lenses is always virtual, whatever the distance of the object; that is, whether the rays of light passing through a concave lens were originally divergent or parallel (Fig. 15).

Rays of light parallel to the axis diverge after passing through a concave lens, and if their direction be continued backward, they will meet at a point called the principal focus (Fig. 15, P F).

The image of an object formed by a convex lens is actual, and is formed by the meeting of rays. This image can be projected on a screen. The image of an object formed by a concave lens is virtual, and is formed by the prolongation backward of diverging rays. This image can be seen only by looking through the lens.

The relation in size between object and image depends upon their respective distances from the optical center of the lens. If the object is placed at a greater distance than twice the principal focus, the image is real, inverted, and smaller. If the object is placed at exactly twice the distance of the principal focus, the image will be real, of the same size, and inverted. If the object is just beyond the principal focus, the image will be real, enlarged, and inverted. If the object is placed at the principal focus, the emanating rays will be parallel, and hence no image is formed. If the object be placed nearer than the principal focus, the emanating rays will be divergent and no real image is formed; but by projecting these rays backward they form a virtual image which would appear through the lens as enlarged and erect. In other words, the lens acts as a magnifying-glass.

Cylindric Lenses.—A cylindric lens is a segment of a cylinder parallel to its axis (Fig. 18). Cylinders, as spheres, are divided into convex and concave—plus (+) and minus (−). Light passing through a cylinder in the plane of its axis is not refracted, and acts as though passing through plane glass. Rays of light passing through a cylinder at right angles to or

perpendicular to its axis are made convergent or divergent, depending upon whether the cylinder is convex or concave, for it is in the direction at right angles to the axis that the cylinder

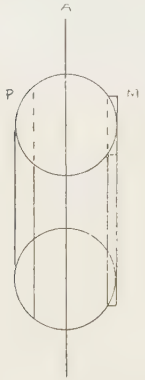


Fig. 18.—*P*, Convex cylindric lens; *M*, concave cylindric lens made from a cylinder; *A*, axis.

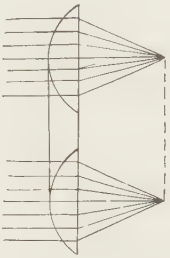


Fig. 19.—The action of a convex cylinder on parallel rays of light.

is curved. Parallel rays of light after refraction by a cylinder are focused in a straight line which corresponds to the axis of the cylinder (Fig. 19). Cylinders used in the trial-case for

Fig. 20.—Cylindric lens.

the estimation of refraction of the eye are marked in their axis by a short linear scratch above and below, and usually as well by having a portion of the surface on each side ground parallel to its axis (Fig. 20).

The Numeration of Lenses.—Lenses are numbered according to their power of bringing parallel rays to a focus—*i. e.*, their refractive power. This is indicated by its principal focal distance, which is the interval between the optical center of the lens and its principal focus. The strength of a lens is inverse to its focal distance, or, in other words, the shorter the distance of the focal length, the stronger the lens, and vice versâ.

The metric, or *dioptric, system* of numbering lenses is practically the only one in use to-day, and will be the only one considered. This system has its unit in a lens which has a distance of one meter for its principal focus. This lens is known as 1.00 diopter, and most always abbreviated D. Every lens is numbered by whole numbers or decimals (1.00, 0.50, 1.25, etc.). A lens which has half a meter for its focal length is twice as strong as the lens which has one meter for a focal length, and is, therefore, written 2.00 D. If twelve times as strong, is written 12.00 D.; if one-quarter as strong, it is written 0.25 D. The focal length of a lens is obtained by dividing 100, representing centimeters, with the number of the lens. Thus a 5 D. lens has a focal length of $100/5 = 20$ cm.

Recognition of the kind of lens is determined by moving the lens before the eye and looking at an object through it. A convex spheric lens moved before the eye will make the object looked at appear to move in the opposite direction. The faster the object moves, the stronger the lens; the slower, the weaker. If the object appears to move with the lens, the lens is concave.

An object viewed through a cylindric lens which is moved in the direction of its axis will not appear to move, but when the lens is moved in the direction at right angles to its axis, the object will move with or against the lens, depending upon whether the cylinder is concave or convex respectively.

The strength of a lens is determined by neutralization. Lenses of the opposite kind and of known strength are taken from the trial-case and placed exactly over the center of the lens to be neutralized. The lenses held in this position are then moved in front of the eye as before. The lens which neutralizes

the lens tested will stop all apparent motion of the object looked at. The ability to pick from the trial-case the proper neutralizing lens is gained with practice. This method of neutralization is the only really accurate means for testing the strength of a lens. The lens measure (Fig. 21) furnishes a quick and reasonably accurate method of determining the character, strength, and astigmatic axis of any lens.

Fig. 21.—The lens measure.

The center of the lens, unless purposely decentered for prismatic effect, should correspond to the geometric center of the lens. This is determined by looking at two lines, which cross each other at right angles, through the lens held a few inches away (Fig. 7). The portion of the vertical and horizontal lines seen through the lens are made continuous with the portions seen beyond the lens; and the two lines should then cross at the exact geometric center of the lens.

CHAPTER II

GENERAL OPTICAL CONSIDERATIONS OF THE EYE

For purposes of study the eye may be looked upon as an optical instrument similar to that of a camera. Like the camera, the eye, by means of its refracting system, forms a small inverted image of surrounding objects on the retina. The retina is comparable to the ground-glass or sensitive plate of the camera, the lens to the lens of the camera, and the iris corresponds to the iris-diaphragm of the camera. Both iris and iris-diaphragm exercise the same function in each—that of regulating the amount of light entering the eye or camera, and also diminishing or eliminating chromatic or spheric aberration. The stimulation produced by this picture on the retina is transmitted by means of the optic nerve to the brain, when the picture seen by the eye is perceived by the brain.

Just behind the delicate sensitive retina is a pigment-layer which absorbs some of the rays of light entering the eye and prevents reflection of rays to other parts of the retina, which would produce a marked dazzling and materially interfere with vision. Such an unfortunate condition is found in albinos, who have a congenital absence of pigment throughout the body. Albinos, as a consequence, always have very poor vision.

In order that distinct and accurate binocular single vision may be obtained, the following conditions are necessary: (*a*) A well-defined inverted image of the object must be formed on the retina at the fovea centralis of each eye. This, of course, has reference to a normal eye from the refractive standpoint. (*b*) This impression, received on the two retinæ, should be conveyed to the brain, the brain having a well-developed binocular

center. This center may be congenitally absent, as is the condition in cases of true alternating strabismus, or it may be undeveloped, as in early childhood. In cases where there is true absence of the binocular center, images may fall on corresponding points of the two retinæ, and yet the brain perceives them as but one monocular image, there being no brain fusion. This question will be more fully dealt with in a subsequent chapter.

The Standard Eye.—It has been found necessary, for purposes of exact calculation, to consider the standard eye as one in which the nodal point (optical center) is 7 mm. behind the anterior surface of the cornea and 15 mm. from the fovea centralis. Such an eye would have an anteroposterior measurement of 23 mm. if we allow a millimeter for the thickness of the choroid and sclera. Such an eye is considered normal, and is called emmetropic. Parallel rays of light entering an emmetropic eye in a state of rest come to a focus on the macula.

The Refractive Apparatus of the Eye.—Rays of light entering an eye pass through the cornea, the aqueous humor, the lens, and the vitreous humor. The refracting surfaces of an eye are the cornea and the anterior and posterior surfaces of the lens. The refracting media of the eye are the aqueous, the vitreous, and the substance of the lens. The action of the dioptric or refracting system of the eye is similar to that of a biconvex lens whose focus is 23 mm., and will consequently focus parallel rays of light on its macula. The greatest deflection of the rays takes place on the anterior surface of the cornea, and additional deviations take place at the anterior and posterior surfaces of the lens. The effect is one of convergence in each instance. By refraction of the eye is meant the changes which are exerted upon the rays of light by the transparent ocular media when the eye is in a state of rest.

Cardinal Points of the Eye.—These are six in number – two principal points, two nodal points, and two principal foci, all situated on the optical axis (Fig. 22).

The principal points (P, Fig. 22) are two points situated

so closely together in the anterior chamber of the eye that they may be considered as one point. This point is situated about 2 mm. behind the cornea.

The nodal points (N, Fig. 22) are also so close together that they may be considered as one point. This point is situated near the posterior pole of the lens, about 7 mm. behind the cornea. Rays passing through this point are not refracted, and form either the axial or secondary rays.

The first principal focus (A, Fig. 22) is that point on the axis where rays parallel in the vitreous meet, and is situated about 14 mm. in front of the cornea.

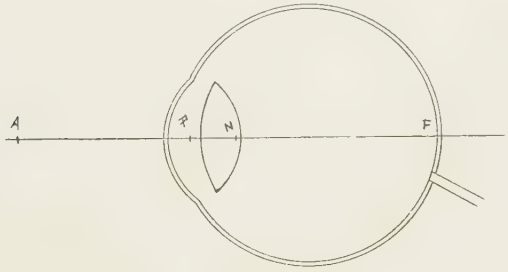


Fig. 22.—Cardinal points of the eye.

The second principal focus (F, Fig. 22) is that point in the axis of the eye where parallel rays meet after being refracted by the dioptric apparatus of the eye. This point is situated between the fovea and the optic disc, about 23 mm. behind the cornea.

The optical axis (F A, Fig. 22) is the line connecting the center of the cornea, the nodal point, and the posterior principal focus.

The visual line (O M, Fig. 23) is a line passing from the object looked at, through the nodal point, to the macula.

The visual angle is an angle formed by rays of light from the extremity of an object passing to the nodal point of the eye. This angle is often called the angle of view. Rays of light from the extremity of an object directed to the nodal point of the eye

pass through unrefracted, and, continuing their straight course, fall upon the retina, forming an inverted image of the object (Fig. 23).

The angle gamma is the angle formed by the optical axis with the visual line. It varies with the refraction of the eye,

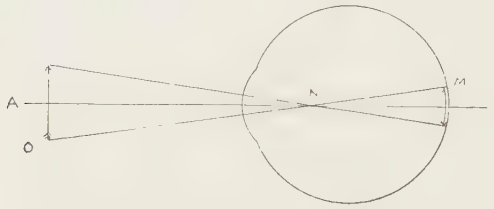


Fig. 23.—Visual lines and the visual angle.

being about 5° in emmetropia, larger in hypermetropia, and smaller in myopia (Fig. 23, A N O).

The angle alpha is the angle formed by the visual line with the major axis of the corneal ellipse.

Minimum visual angle is the smallest visual angle in which the normal eye can still correctly recognize an object. The

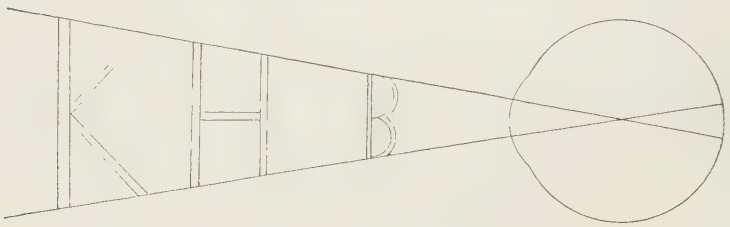


Fig. 24.—Minimum visual angle.

letter B in Fig. 24 is recognized at 6 meters as B; and is plainly seen, but if placed at a greater distance than 6 meters, it would form a smaller visual angle and could not with certainty be called B. To be seen at 12 meters and still occupy the same visual angle it would have to be twice as large—the same size as H in Fig. 24. To be seen at 24 meters it would have to be four times the size, as K in Fig. 24. B, H, and K in

Fig. 24 can be seen closer to the eye than 6, 12, and 24 meters, but the purpose is to find the greatest distance from the eye at which they can be seen, and this represents the maximum acuteness of vision.

Standard of Visual Acuity.—It was essential to have a standard visual acuity which would be consistent with the

Fig. 25.—Two of Snellen's test-types ("American Text-book of Diseases of Eye, Ear, Nose, and Throat").

standard or emmetropic eye, and in this way have a definite method of recording numerically any departure from this standard vision. The standard visual acuity is the power of the eye to distinguish letters or characters occupying an angle of five minutes. Every letter of the test-card is so proportioned that it will measure just five minutes in the vertical and horizontal meridians, and reducible to twenty-five squares, each measuring one minute horizontally and vertically (Fig. 25). The F in Fig. 25 is drawn in a five-minute square, and each stroke of the letter, and the space between the strokes, measures just one minute in width. The tangent of the angle of five minutes is expressed by the decimal 0.001454, and in order to calculate the size of any letter or character which should be seen clearly at a definite distance, it will be necessary to multiply the distance in millimeters by this tangent of the angle of five minutes. Letters on this scale are standard letters, and are arranged in charts or test-cards. The best known are those of Snellen (Fig. 26).

Fig. 26.—A test-card (Snellen).

REFRACTION OF THE EYE

Emmetropia, or the normal eye, is an eye so constructed that parallel rays of light come to a focus on the retina when this eye is in a state of rest (Fig. 27, E).

Ametropia.—When parallel rays of light are *not* focused on the retina of an eye in a state of rest, that condition is called ametropia. Ametropic eyes have errors of refraction which are of three varieties—*hypermetropia*, *myopia*, and *astigmatism.*

Hypermetropia is that form of refractive error in which the anteroposterior axis is too short. In such an eye parallel rays of light do not focus on the retina, but *behind* the retina (Fig. 27, H).

Myopia is that form of refractive error in which the anteroposterior axis is too long. In such an eye parallel rays of light come to a focus *in front of* the retina (Fig. 27, M).

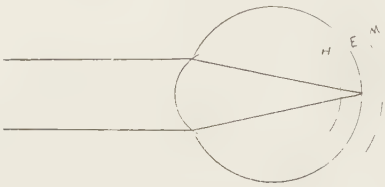


Fig. 27.—Focus of parallel rays of light in hypermetropia, emmetropia, and myopia.

Astigmatism is that form of ametropia in which the refractive condition of the two principal meridians is different.

Presbyopia is due to the gradual receding of the near-point as age advances. At about the age of forty-five in the emmetropic eye the near-point has usually receded to 22 cm., and the need of a convex glass to make up for the loss of elasticity in the crystalline lens becomes manifest.

As a general rule, the two eyes of an individual are similar in their refractive condition, but there may be a wide variance in this respect. One eye may be emmetropic and the other highly hypermetropic; one myopic, and the other hypermetropic; or there may be a great difference in a similar kind of ametropia. *Anisometropia* is the term usually applied when the two eyes vary to a marked degree in their refraction.

Accommodation is the power of altering the focus of the eye so that rays of light emanating from different distances at different times will be brought together on the retina. The focusing of rays arising from a distance nearer than 6 meters is accomplished by an increase in the convexity of the lens, which thus alters its refractive power. An eye cannot focus

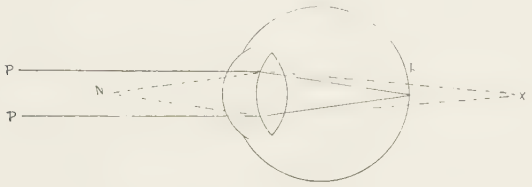


Fig. 28.—The emmetropic eye at rest.

rays of light upon its retina from different points at the same time. Parallel rays of light come to a focus on the retina of the normal eye at rest (P R, Fig. 28), but rays coming from a near object are divergent and focused behind the retina (N X, Fig. 28); hence near objects are blurred and distant objects are plainly seen. If, now, the near object is looked at, the refractive power

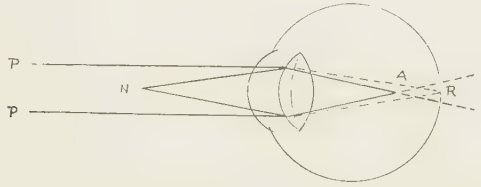


Fig. 29.—The emmetropic eye in accommodation.

of the eye is changed by accommodation—parallel rays of light will be brought to focus in front of the retina (P A, Fig. 29), and the divergent rays emanating from the near object will be brought to a focus on the retina (N R, Fig. 29), in which case the near object appears clear and the distant object blurred.

Mechanism of Accommodation.—The ciliary body is circular in form and occupies a triangular area in the eye just beneath the sclera at approximately its corneal junction. A

portion of the ciliary body is composed of muscular fibers, known as the ciliary muscle. This muscle is divided into three parts, according to the arrangement of its fibers: (1) Radiating; (2) circular or sphincter fibers; (3) meridional. The radiating fibers are fan-shaped and are scattered throughout the ciliary body. The circular fibers, occasionally called the muscle of Müller, are the most important fibers of the ciliary muscle; they form a sphincter ring concentric with the equator of the lens. The meridional fibers are the longest of all, and lie next to the sclera and parallel with it, passing backward to the choroidal coat of the eye.

During accommodation the ciliary muscle contracts, draws forward the choroid, and, especially through the action of the sphincter, narrows the circle surrounding the lens, and thus relaxes the suspensory ligament of the lens, which is attached to the ciliary body well forward on its inner side. This relaxation of the suspensory ligament allows the lens, by its own elasticity, to become more convex. The increase in convexity is chiefly noticeable on its anterior surface (Fig. 30).

Fig. 30.—Change in shape and refraction of the lens in accommodation.

Accommodation is accompanied by contraction of the pupil, a narrowing of the anterior chamber, and a convergence of the visual lines.

Far-point (punctum remotum—p. r.) is the farthest point of acute vision when the eye is in a state of rest, that is, when there is no contraction of the ciliary muscle. In the normal, emmetropic eye the far-point is infinity.

Near-point (punctum proximum—p. p.) is the nearest point of acute vision when the eye is exerting its greatest accommodative effort.

The near-point is determined by noting the shortest distance at which the patient can read the smallest type (Snellen 0.37 m. Fig. 31) with each eye separately.

.37 M.

If you gather apples in the sunshine, or make hay, or hoe corn, and then retire within doors and shut your eyes and press them with your hand, you shall still see apples hanging in the bright light with boughs and leaves thereto, or the tasselled grass, or the corn-flags, and this for five or six hours afterwards. There lie the impressions on the retentive organ though you knew it not. So lies the whole series of natural images with

.50 M.

Our age yields no great and perfect persons. We want men and women who shall renovate life and our social state, but we see that most natures are insolvent; cannot satisfy their own wants, have an ambition out of all proportion to their practical force, and so do lean and beg day and night continually. Our housekeeping is mendicant, our arts, our occupations, our marriages, our religion we have not chosen, but society has

.62 M.

it is best to pay in your land a skilful gardener, or to buy good sense applied to gardening; in your sailor, good sense applied to navigation; in the house, good sense applied to cooking, sewing, serving; in your agent, good sense applied to accounts and affairs. So do you multiply your presence, or spread yourself throughout your estate. But because of the dual constitution of things in

.75 M.

A wise man will extend this lesson to all parts of life, and know that it is always the part of prudence to face every claimant and pay every just demand on your time, your talents, or your heart. Always pay; for first or last you must pay your entire debt. Persons and events may stand for a time between you and justice, but it is only a post

1. M.

There are days which occur in this climate, at almost any season of the year, wherein the world reaches its perfection, when the air, the heavenly bodies, and the earth, make a harmony, as if nature would indulge her offspring; when, in

1.25 M.

Reason for one is seen to be reason for another, and for every other. There is a middle measure which satisfies all parties, be they never so many, or so resolute for their own.

1.50 M.

There are geniuses in trade, as well as in war, or the state, or letters; and the reason why this or that man is fortunate, is not to be told. It lies in the man: that is all any-

2 M.

All things show us, that on every side we are very near to the best. It seems not worth while to execute with too much pains some one intellectual, or civil

Fig. 31.

The distance between the near-point and the far-point is the *range of accommodation.*

The amplitude of accommodation is the difference in the refractive condition of the eye in a state of rest, and when its maximum amount of accommodation is in force. An emmetropic eye, for instance, has infinity for its far-point, and if 10 cm. distance is the near-point, the difference between the lens of the eye adopted for infinity and 10 cm. will be 10 D., as the focal length of a 10 D. lens is 10 cm. In this instance the amplitude of accommodation is 10 D. This can be determined in another way by dividing 100 by the near-point in centimeters. If the near-point is 15 cm., the amplitude of accommodation is 100/15, or $6\frac{2}{3}$ D. This rule applies only to the emmetropic eye.

The power of accommodation gradually recedes as age advances, due largely to a loss of elasticity in the lens-fibers, but due partially to a weakness of the ciliary muscle. In emmetropic eyes it may be given as a general rule, to which there are exceptions, that the near-point at ten years of age is 7 cm.; at twenty years, 10 cm.; at thirty years, 14 cm.; at forty years, 22 cm.; at forty-five years, 28 cm.; at sixty years, 100 cm.; and at seventy-five years, practically infinity. The following table gives the amplitude of accommodation and near-point of the emmetropic eye from the ages of ten to seventy-five years:

Year.	Near-point.	Amplitude in Diopters.
10	7.0 cm.	14.00
15	8.5 "	12.00
20	10.0 "	10.00
25	12.0 "	8.50
30	14.0 "	7.00
35	18.0 "	5.50
40	22.0 "	4.50
45	28.0 "	3.50
50	40.0 "	2.50
55	55.0 "	1.75
60	100.0 "	1.00
65	133.0 "	0.75
70	400.0 "	0.25
75	∞	0.00

In ametropic eyes the amplitude of accommodation is determined with the refractive error for distance fully corrected and worn.

In hypermetropia the far-point is beyond infinity, for parallel rays of light are only focused on the retina in hypermetropic eyes by accommodative effort. If the patient is compelled to use 1 D. of accommodative effort to focus parallel rays of light on his retina, and his near-point is 20 cm., his amplitude of accommodation would be $100/20=5+1=6$ D. Consequently, with an amplitude of accommodative equal to an emmetropic eye, the near-point in the hypermetropic eye would be farther away, as part of the accommodative effort is used in focusing parallel rays.

The Amplitude of Accommodation in Myopia.—In myopia a concave lens is necessary to focus rays of light on the retina, as parallel rays of light come to a focus in front of the retina of a myopic eye. Consequently the far-point of a myopic eye is within infinity—*i. e.*, is always positive. The near-point of a myopic eye is always nearer than that of an emmetropic eye for the same age, and depends upon the distance of its far-point. The amplitude of accommodation is determined by finding the near-point in centimeters and dividing 100 by this; from the result is then subtracted the strength of the concave lens necessary to focus parallel rays, thus: near-point, 8 cm., and the myopia is 4 D.; amplitude of accommodation will be $100/8=12.5$ D. -4 D. $=8.5$ D.

Convergence.—In considering accommodation we have spoken of it only in connection with one eye. When there is binocular vision, convergence is associated with accommodation. Convergence is due principally to the action of the internal recti, which turn the visual lines of the eyes toward the near-point. In looking at distant objects the visual lines are parallel; in looking at a near object, the visual lines converge.

The angle which the visual lines make in turning from a distant object to a near one is called the *angle of convergence*, and the angle which is formed at one meter distance by the

visual axis with the median line is called the meter angle (M. A.), also called the unit of the angle of convergence (Fig. 32). If the eyes look at an object half a meter distant, the convergence is twice the unit, and convergence equals 2 M. A. If directed toward an object one-fourth meter distant, the convergence is four times the unit, or 4 M. A. If directed toward an object 2 meters away, the convergence is one-half the unit, or ½ M. A. (Fig. 32).

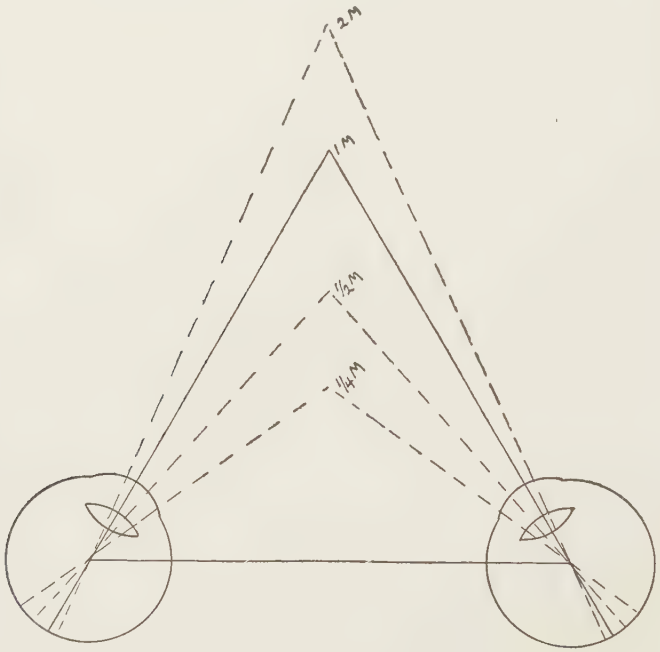


Fig. 32.—The meter-angle of convergence.

The emmetropic eye in binocular vision requires as many meter angles of convergence as it needs diopters of accommodation. To see an object distinctly at 1 meter requires 1 meter angle of convergence and 1 diopter of accommodation; at 4 meters an object, to be seen distinctly, requires 0.25 meter angle of convergence and 0.25 D. of accommodation; at 10 cm. a 10 meter angle of convergence and 10 D. of accommodation.

The Amplitude of Convergence.—The far-point of convergence is the point to which the visual lines are directed when the eyes are in a state of rest. The near-point of convergence is the point to which the visual lines are directed when there is the greatest amount of convergence. The difference between these two points gives the amplitude of convergence, and it is expressed in the greatest number of meter angles of convergence of which the eyes are capable.

Determining the vision is finding the seeing power of the unrefracted eye. It is needless to mention the fact that the visual power of an eye must not be confounded with the refraction of an eye. In other words, an emmetropic eye with optic atrophy may have little or no visual power and yet its refractive condition may be normal. The most acute vision is central, *i. e.*, situated at and immediately around the fovea centralis. To determine the vision, cards are employed on which are printed test-type letters, or characters of various sizes, all constructed so that each subtends an angle of five minutes. The characters or letters are usually black on a white background (Fig. 26). The top letter should be seen by the normal eye at a distance of 60 meters (200 feet); the bottom letters should be seen at 3 meters (10 feet); the intervening letters at the distances indicated.

Gould has recommended a black card, on which are constructed white letters, which is supposed to have the advantage of bringing out the letters more prominently (Fig. 33).

For illiterates, or those who do not know English letters, a dummy, or illiterate, card is made with characters consisting of lines shaped like the capital E. These letters, like Snellen's, are made to conform to a 5 minutes angle (Fig. 34).

Method of Determining and Recording Vision.—The test-card or cards are hung on a wall at 6 meters' distance from the patient. The 6/6 or 20/20 line should be placed just a trifle below the level of the patient's eyes, and the card should be evenly illuminated by artificial light. Artificial light is constant, and gives much more uniform results than daylight. A distance of

6 meters or more is preferred to any less distance, but should a physician's office be of less length than this, he can use the diagonal distance, or a plane mirror for reflecting the letters of a specially prepared test-card with reversed letters. A distance of less than 5 meters is of little value.

The record of vision is usually made in fractions. The numerator always indicates the distance between the patient and the card. If this is 6 meters (20 feet), the numerator is 6 or 20, depending upon whether meters or feet are understood. The more common in this country is 20. The denominator indicates the size of type read at the distance indicated by the numerator.

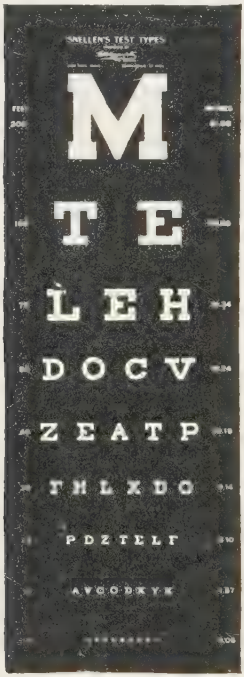


Fig. 33.—White-on-black test-type card.

Fig. 34.—Snellen's test-type card for illiterates.

If a patient seated 20 feet from the test-card reads the line marked 20, the vision is 20/20, or normal; if able to read only as low as the line marked 40, the vision would be 20/40, or $\frac{1}{2}$ normal; if the large letter at the top is all that is seen, the vision will be 20/200 or 1/10. If most of the letters on the 20 line are read, the vision would be 20/20−; if only a few on

this line are read, the vision would be 20/30+. Another method is to use a dot or question mark for each miscalled letter, thus: 20/20 . . . , or 20/20 ? ? ? .

If an eye cannot read any letter on the card at the distance it is hung, the card is advanced toward the patient until he can just make out the large letter at the top. If this was recognized at 5 feet, 5 would be the numerator and 200 the denominator, or 5/200=1/40. If letters cannot be seen at any distance, the physician can hold his fingers before the patient's eye and have him count them. The vision is recorded, "fingers at 2 feet," "fingers at 6 inches," etc. An eye unable to count fingers may be able to see the motion of the hand or an object passed before the eye. The vision is then termed "*shadows*." Eyes unable to recognize "shadows" may still be able to tell light from dark, and this is tested by flashing light reflected from a mirror into the eye. This is termed light perception—abbreviated l. p.

Testing the Near Vision.—This is determined by the employment of a card on which are printed words or sentences, so that each letter subtends an angle of 5 minutes, at a given distance from the standard eye. The best known card is Snellen's (Fig. 31), which is marked from 0.37 m. to 2 m. Snellen's 1 m. is practically the same as newspaper type.

The patient is seated so that the light will fall on the card and well illuminate it. The physician then requests the patient to read the smallest type on the card he can see or spell, and the card is gradually moved toward the patient until the letters become blurred. The nearest point to the eye at which they can be read is measured, and this, with the type size, is recorded. If in Fig. 31 the type marked 0.62 m. is able to be read at 10 cm. distance and no closer, the record will read: "near-point is 10 cm., with type 0.62 m." If the patient is presbyopic, the near-point will have to be determined with a convex sphere, and this is added to the record thus: "near-point, 15 cm., with type 0.62 m. + 3.00 sph." Each eye should, of course, be tested separately, as should be the case in testing the distant vision.

CHAPTER III

EQUIPMENT NECESSARY FOR PROPER REFRACTION

For purposes of refraction a physician's office should be of good size, or of sufficient length to enable him to place the test-cards at a distance of at least 5 meters from the patient. Six or 7 meters' length is to be preferred to 5, as rays of light

Fig. 35.—Thorington's chimney.

Fig. 36.—Ophthalmoscopic incandescent lamp with spiral filament.

emanating from an object 6 or more meters away may be said to be parallel just before entering the eye. The room should be papered or painted in some dark shade without a gloss, for in this way reflections are done away with. Windows should be supplied with the darkest green shades, so that the room can be made absolutely dark. A small dark room, 4 by 5 or 6 feet,

is often preferred to darkening the consulting room. From the office, or special dark-room, all light is excluded except that coming from the burner used for the source of light to be reflected into the eye by the mirror of the retinoscope or ophthalmoscope.

The best light for this purpose is gas. An adjustable bracket is placed at an average height on the wall which permits of regulation suitable to the height of the individual patient. The burner is of the ordinary Argand type, over the chimney of which is placed a Thorington chimney (Fig. 35), which is made of asbestos and blackened, so that little or no light is seen except that coming through a hole in its side. This hole is supplied with an iris-diaphragm, which regulates the amount of light coming from the lamp. If electricity is preferred to gas, a bulb similar to Fig. 36 may be used for illuminating purposes.

Fig. 37.—Meyrowitz alternating test-type cabinet.

The test-cards are hung on a blank wall, which should be painted or papered a dark, dull color, even if this is not true of the rest of the room. The cards should be evenly illuminated by artificial light. For this purpose electricity is superior to gas, and, on the whole, is more satisfactory. An excellent test-type cabinet is shown in Fig. 37. With this cabinet, by

means of an electric connection operated from the physician's seat near the trial-case, the type can be changed rapidly and easily. This is quite necessary, as the patient soon becomes familiar with the letters on a single card. Another very good test-cabinet is Covell's (Fig. 38). In this cabinet the test-types are mounted on a spring roller, which is operated by the physician at the trial-case with a single cord. Besides the regular test-types, a single dot for muscle testing and half an astigmatic dial can be brought into view. The cabinet is electrically illuminated, so that the types can be seen either by transparent or reflected light.

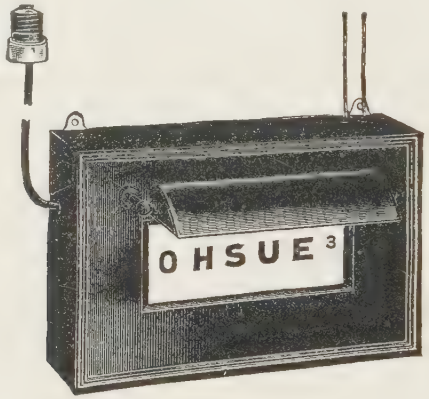


Fig. 38.—Covell's test-type cabinet.

The patient should be seated, with his back to the windows, 5 meters or more directly in front of the test-cards or test-cabinet. The chair in which he sits should be comfortable, as the process of examination is often long and tedious. Immediately at the patient's right is a small table on which is placed the trial-case, containing the lenses necessary for practically every possible combination (Fig. 39). A good trial-case should contain 40 pairs of convex and concave spheres, and 30 pairs of convex and concave cylinders. The spheres (Fig. 40) increase 0.12 D. in strength up to 1.75 D.; from 1.75 D. to 4.00 D. they increase 0.25 D. in strength; from 4.00 D. to 7.00 D., by 0.50 D.;

from 7.00 D. to 16.00 D., by 1.00 D.; and from 16.00 D. to 20.00 D., by 2.00 D. The cylinders are the same except that

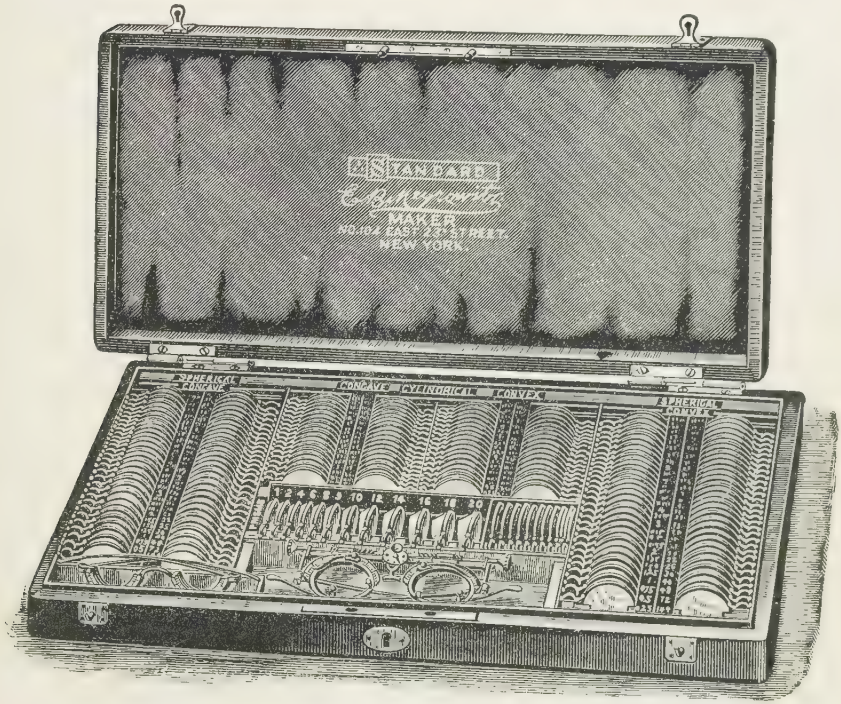


Fig. 39.—A trial-case.

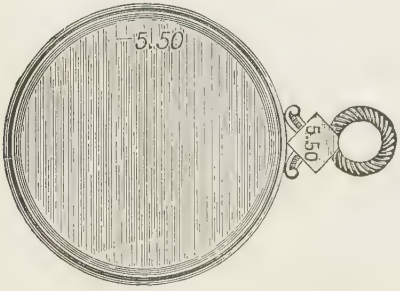


Fig. 40.—Spheric test lens.

they run no higher than 8.00 D. It is advisable to have cylinders of at least 10 D. in strength. The prisms in such a case range

from $\frac{1}{2}$ to 20 $\triangle^{\circ}$ in strength. The case should also contain red and green lenses; a plane glass lens; smoked lenses of various density; a stenopeic slit (Fig. 41); a pin-hole disc (Fig. 42); a Maddox rod for muscle testing (Fig. 43); a rotary prism after the plan of Risley's (Fig. 44); and a blank for covering one eye

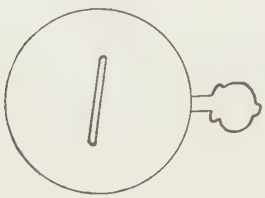


Fig. 41.—Stenopeic slit.

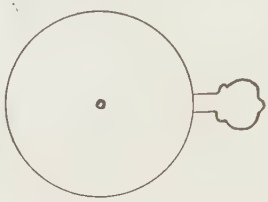


Fig. 42.—Pin-hole disc.

while the other is being tested. This trial-case equipment will be sufficient to test the ametropic condition of any patient presenting himself with symptoms of asthenopia. A small case containing a set of bifocal lenses is of value for presbyopic patients. After the amount of presbyopia is determined, these

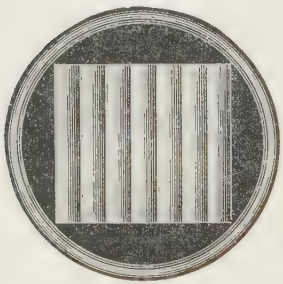


Fig. 43.—Maddox rod.

Fig. 44.—Risley's rotary prism.

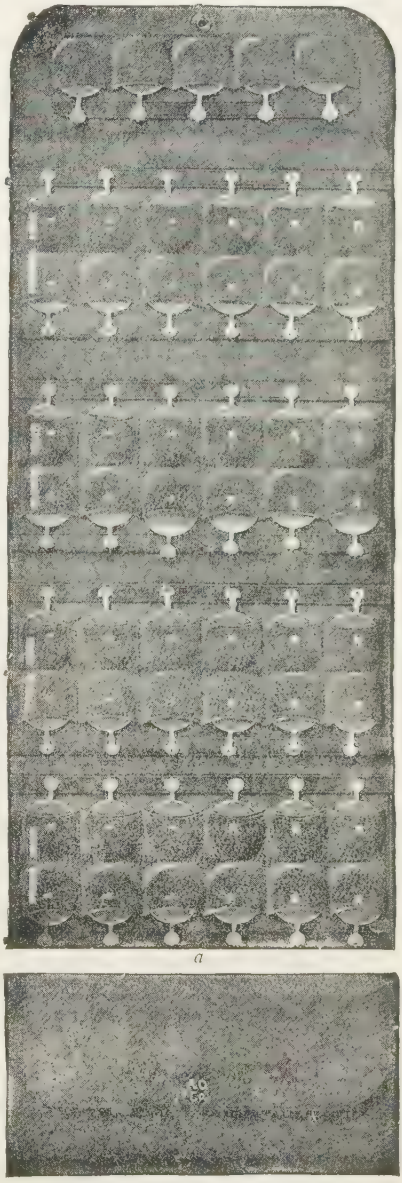
bifocal lenses can be placed in the frames, and the patient is thus enabled to judge the effect of this type of lens. The upper or distant part of the bifocal set is plane glass, and the lower part convex spheric; the strength increases by 0.25 D. up to 1.50 D., and from 1.50 D. to 4.00 D., the strength increases by 0.50 D.

Another small trial-case containing convex and concave

spherics and cylinders is of distinct value for purposes of retinoscopy. This set can be placed near the light used for reflection, and saves carrying the large trial-case about the office. This small case can also be used for rough bed-side refraction, or for testing the eyes of patients who are unable to come to the office. A convenient pocket-case for such work is shown in Fig. 45.

The ophthalmoscope was formerly more frequently used for purposes of refraction. We now have simpler and more accurate methods of measuring the refractive error, and this valuable instrument is now used almost exclusively for examining the details of the fundus. As it is necessary for every physician who intends to do refraction to be able to examine accurately the fundus of the eye, the Ophthalmoscope and How to Use It will be taken up in a separate chapter.

The retinoscope (Fig. 46) is a mirror used for reflecting light in the patient's



a

b

Fig. 45.—A pocket trial-case: *a*, Open; *b*, closed.

eye. As shown in the cut, the instrument has a handle of sufficient length for the operator to hold conveniently, and the mirror contains a central hole, which is held immediately in front of the eye of the physician. This hole may be either cut through the glass, or made by removing the silvering. Thorington's retinoscope (Fig. 47) differs from the ordinary

Fig. 46.—A retinoscope.

Fig. 47.—Thorington's retinoscope.

one in that the mirror is 2 cm. in diameter on a round, 4 cm. metal disc, and has a 2 mm. sight-hole in the center. The mirror of the retinoscope may be either plane or concave. It is best to use one kind and stick to this, as the shadow seen in the eye with the retinoscope moves in the opposite direction with a concave mirror than the direction seen when a plane mirror is used. The plane mirror gives more accurate results in my hands than the concave, and is the kind most frequently

used. Refraction by retinoscopy is described in the chapter on Methods of Refraction.

The ophthalmometer is an instrument devised to measure the corneal astigmatism. The best known is that of Javal-Schiötz; Fig. 48 shows the latest (1907) model of this instrument. The ophthalmometer measures the corneal curvature by means of images of mires reflected on the cornea and reviewed though a telescope.

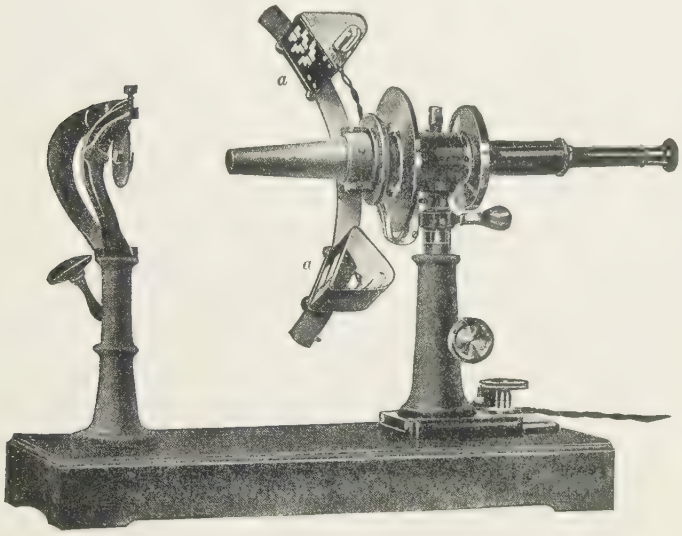


Fig. 48.—The Javal-Schiötz ophthalmometer.

The ophthalmometer consists of a telescope which contains a birefrangent prism placed between two biconvex lenses. Attached to this telescope is a graduated arc, upon which are placed two transilluminated mires (Fig. 48, A, A). The left mire is made up of two 3 cm. squares separated by a black line; the right mire is graduated into steps, each 5 mm. wide; a black line passes through the middle of these steps. The telescope is mounted on a movable tripod for purposes of focusing the corneal images. The ophthalmometer should be

placed on a special table, which can be raised or lowered to suit the height of the individual patient.

The patient is seated on the side of the instrument, provided with a chin and forehead rest, and faces the mires and the telescope. The mires each contain a set of small electric bulbs

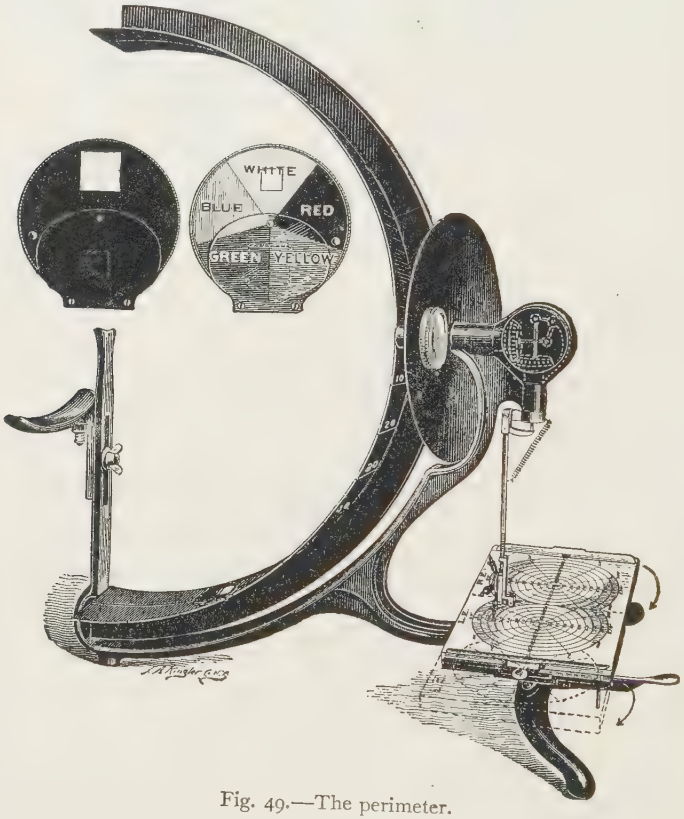


Fig. 49.—The perimeter.

which illuminate them. The current may be obtained from a set of dry cells or through a rheostat from the regular lighting current. The room should be darkened somewhat in order to bring out the corneal images.

The perimeter (Fig. 49) is an instrument designed for recording the field of vision. It consists of a quadrant or arc

which can be revolved to the position of any meridian of the eye. The quadrant is marked in degrees, 0 being center point, and 90 at either extremity. The patient is seated before the instrument, his head resting on a chin-rest, and the eye to be examined is placed directly in front of the center of the arc. The eye not being tested is covered, while the one to be tested is directed toward the center of the arc. The test-object is a white square which is carried along the inner surface of the arc, and the point where it is first seen in the different meridians is recorded on a chart provided for this purpose, on which is marked the boundary of the normal field (Fig. 50).

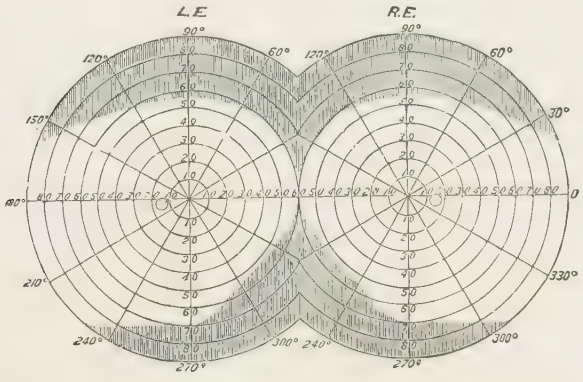


Fig. 50.—The perimeter chart.

Alterations in the field of vision are defects and limitations. A defect in the field is called a *scotoma*, one of which is normal for every eye—the area of the optic disc. Scotomata are called central or peripheral, according to their location. A central scotoma is more noticeable to the patient, as it corresponds to the point of fixation, and, when marked, materially interferes with or destroys central vision. Scotomata may be negative, when they exist in the field without being noticed by the patient until the field is examined, or positive, when they are seen by the patient as black spots or a cloud in the visual field. Positive scotomata are due to changes in the media, and may be motile.

Negative scotoma may be absolute, in which case perception of light is lost in the defective area, or relative, when perception

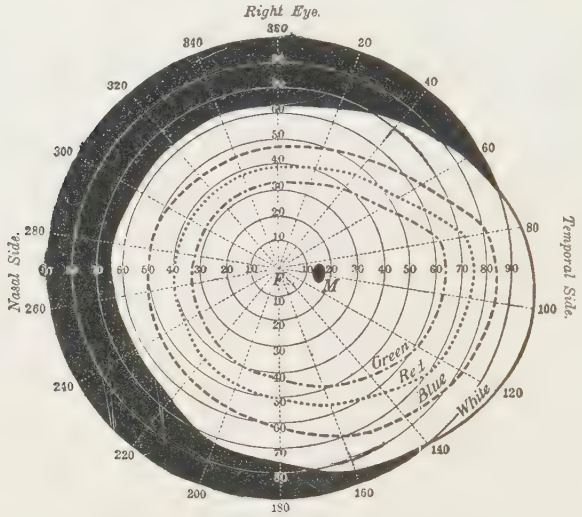


Fig. 51.—Field of vision of the right eye for white, blue, red, and green for a test object of 20 square millimeters (after Baas) (Fuchs): *F*, Point of fixation; *M*, Mariotte's blind spot.

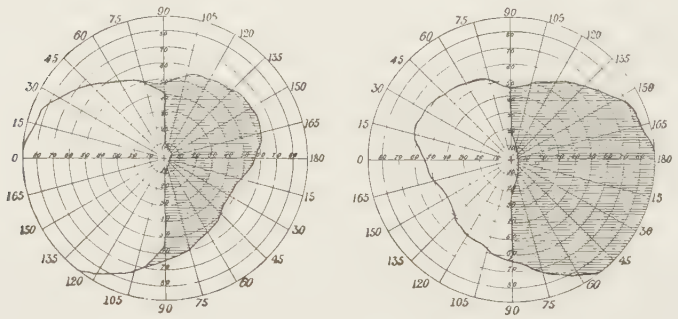


Fig. 52.—Fields of vision in right homonymous hemianopsia (from a case under the care of Dr. Wharton Sinkler) (de Schweinitz).

of light is only diminished in the defective area. Relative scotomata may have a loss in color perception. For detection

of scotomata test objects of from 2 to 5 mm. in diameter should be used.

The color fields (Fig. 51) are more contracted than the field for form or white. Blue is the widest, red the next, and green the smallest field.

Limitation of the field of vision may assume an even contraction in all meridians, when it is known as concentric. The contraction may be irregular, or there may be a loss of one side or the other.

Concentric contraction affects all the periphery equally, and when marked, may leave nothing but central vision. This condition is found in retinitis pigmentosa. Contraction may affect but one side or the other of the field, in which case it is called nasal or temporal contraction, or upper or lower contraction. When one-half the field is absent, the condition is called *hemianopsia* (Fig. 52).

The perimeter is also used for determining the amount or degree of squint.

CHAPTER IV

THE HISTORY OF THE PATIENT

It would seem at first glance that the history of a patient who applies to a physician for glasses is hardly important enough to deserve the dignity of a special chapter. Careful consideration, however, will show the great importance of a thorough history of each case, and I shall endeavor to point out the bearing a history has on a purely refractive case. Refraction is not the mere mechanical measuring of an ametropic eye, or the placing of trial-lenses before the eyes until the best vision is obtained and this glass prescribed. It is a finer art than this, and requires skill, ingenuity, a well-grounded knowledge of the subject, a thorough conversance with the many reflex causes of asthenopia, and a limitless patience.

Headache is undoubtedly the symptom above all others that leads patients to consult an oculist, or for which so many physicians refer their patients. Headache is only a symptom, but much can be told from its character, its location, its duration, and its time of appearance. A dull headache, coming on irrespective of use of the eyes, and frontal in location, may be due to digestive disturbances, constipation, menstruation, and bodily fatigue following excitement or emotion. A dull frontal headache coming on only after the use of the eyes, never present in the early morning or on days when the eyes are not used, is usually due to an uncorrected or badly corrected refractive error. The refractive error usually found in such cases is hypermetropia or a compound hypermetropic astigmatism, and is due to the fact that the eye is anatomically short and the ciliary muscle is in constant contraction in order to obtain a distinct image. In neurasthenics the headache is frequently

in the occipital as well as in the frontal region. Frequent headache on the top of the head, either alone or combined with pain in the occipital region or the region of the seventh cervical vertebra, may be either neurasthenic in origin or coincident with a general lack of nerve tone, due to a debilitating disease or mental worry. These cases seldom show any refractive error of appreciable amount. If, however, a refractive error of more than 0.50 D. is found, some benefit may be expected from the use of suitable lenses, but the greatest good is obtained through the building up of the lowered nerve tone.

Morning headache, which gradually passes away toward the middle of the afternoon, may be due to digestive disturbances, or more commonly to acute or chronic disease of one or more of the accessory sinuses of the nose. Sharp, radiating, neuralgic pain, especially if unilateral, is almost invariably due to nasal or accessory sinus trouble. This type will usually be more severe in the morning.

Migraine is usually associated with digestive trouble, and if seen in early years, is amenable to proper treatment, especially directed toward the cause. Many cases of migraine are relieved by the proper correction of refractive errors or errors in muscle balance. Appropriate general treatment and prophylaxis should be combined with the local treatment of the eyes.

My observations agree with those of Gould, who has repeatedly stated that the pelvic regions of far too many women are operated upon. These women would in many instances get absolute relief from the proper correction of refractive errors. It seems to have become the fashion, for married women especially to consult the gynecologist for symptoms which naturally point toward eye-strain, and yet are supposed to indicate pelvic disorders. The profession, at least, should realize that many women are operated upon who could have received marked relief through the correction of ocular defects.

The occupation of a patient is of the greatest importance in the proper correction of refractive errors. This becomes of the utmost importance when the patient's eyes are in a condition

of presbyopia. This subject will be gone into more in detail later, but it must be at once evident that the carpenter would require a glass of different focus than that of the watch-maker. The student would need the correction of a lesser refractive error than the sailor. The examples could be enumerated indefinitely, but enough have been given to show the necessity for carefully considering occupation.

Habits are of almost equal importance with occupation. Red and swollen eyelids may be caused by straining the eyes in an endeavor to overcome an uncorrected or badly corrected refractive error, or they may result from late hours, dissipation, irritating dust, habitual crying, or nasal disease.

The general health should be carefully inquired into. Especial attention should be given to recent illnesses, for typhoid fever, malaria, influenza, diphtheria, and other debilitating diseases make manifest a refractive error which will cease to be troublesome when the body has regained its normal physical and nervous tone. Typhoid fever, influenza, and diphtheria commonly give rise to symptoms of asthenopia during convalescence. Such cases should be carefully refracted and the correcting lenses worn constantly for a while. They may be later abandoned if symptoms of asthenopia do not again arise when the lenses are laid aside for a week or two. Diphtheria frequently causes a paralysis of the ciliary muscle, which will need to be temporarily corrected as a presbyopia, for, of course, the accommodation is destroyed and strong convex lenses are needed for near use. Influenza frequently causes little more than symptoms of eye tire, but may give rise to various inflammatory disturbances, which interfere with visual acuity. Several cases have come under my observation in which the vitreous has shown a fine diffuse haze, which caused a reduction in vision of nearly one-half. The convalescence was exceedingly slow, but ultimate vision was good.

A history of nasal or post-nasal inflammation or obstruction should be carefully inquired into, for reflex nasal irritation gives rise to irregular spasm of the ciliary muscle, and hence

a change in the refraction. This is shown by the variation in the astigmatic axis from day to day, and the history that patients have been to various refractionists without relief. Every oculist should be able to diagnose nasal disease, so as to be able to refer their cases intelligently to a rhinologist for operation or treatment. As we recognize the intimacy of the relation between the nose and the eye, fewer cases of monocular pain will be treated by means of morphin, coal-tar products, and lenses. Lenses cannot be of permanent benefit until the astigmatic axis remains constant, and this will not be until the nose has received appropriate treatment.

Sudden failure of sight is never refractive in its cause, but the sudden discovery of a low vision in one eye is frequently refractive. It does not mean that the refractive error has developed suddenly, but that it has been previously unnoticed. Many men first discover defective vision in one or both eyes when they appear before an examiner for railroad or similar work in which a high visual acuity is required. The vision of very many of the cases can be made normal, but only through the use of proper glasses, which, of course, the railroads do not permit, except on the old employees.

The vision of both eyes of all patients who come to an oculist for treatment should be carefully noted in the records, and if defective, an attempt should be made to improve it with suitable lenses. This, of course, is often impossible, but as normal vision in all cases is what we strive for, the visual tests are the best guide we have for judging the progress of our cases. Vision of the good eye should be carefully tested, with lenses, if necessary, in all cases of injury to the eye, especially if the injury is a penetrating one, or there is a possibility of intra-ocular foreign body. By this record we can watch most carefully for any signs of sympathetic ophthalmia.

A simple history of short-sightedness may not necessarily mean myopia. It may even mean a high degree of hypermetropia, hypermetropic or mixed astigmatism. Careful examination will reveal the refractive condition. There is, however, a

condition, not infrequently found in young people, which simulates a myopia in history, in low vision, and which improves when concave spheres are placed before the eyes. Careful questioning will frequently elicit the fact that the short-sightedness developed rapidly, and full mydriasis will show an absence of myopia and frequently an existence of hypermetropia, the low vision in these cases having been caused by spasm of the ciliary muscle giving rise to an artificial myopia.

The toxic amblyopias, acute and chronic, show no fundus change and usually very little refractive error. A correction of the refractive error will give little or no improvement—certainly not enough to warrant the prescribing of lenses. Reading will be impossible because of the central scotoma. The prognosis of this condition is good if the cause is removed, and later glasses may be fitted if necessary.

Any inflammatory condition of the retina or optic nerve will not be benefited by correction of the refractive error. Retinal inflammation should render an examination of the heart and urine imperative.

Syphilis does not in itself cause refractive errors, but may bring on symptoms of asthenopia because of paresis or paralysis of the internal and external ocular muscles.

Cases of strabismus should have their refractive error quite fully corrected and the correction worn constantly for several months before resorting to operative procedure. This phase of refraction will be gone into in detail in a separate chapter.

If the patient presenting himself for examination is wearing glasses, the length of time glasses have been worn should be gone into, and the date of the prescription for the last pair noted. Under ordinary conditions glasses can be worn for from two to three years without reëxamination of the eyes. At the end of this time some change is usually found necessary and beneficial. The professional standing and ability of the previous refractionist may give at once a reason for the present discomfort of the patient. That the refractive condition of the eyes does

change is evidenced by the new findings at intervals varying from two to five years.

Symptoms of asthenopia frequently arise from badly fitting frames and improperly adjusted lenses. Every oculist should insist upon seeing each prescription after it has been filled and the glasses adjusted to the patient. This insures the necessary check on the optician, and one is in this way made certain that the patient is wearing the glasses ordered, and also that they are properly placed before the eyes. The patient should be advised to have the lenses frequently put in proper position and the frames kept in order. Badly adjusted frames may give rise to as severe symptoms of asthenopia as an uncorrected refractive error.

CHAPTER V

MYDRIATICS AND CYCLOPLEGICS

Drugs having the power to produce dilatation of the pupil (mydriasis) are termed *mydriatics*. Most mydriatics also have the power, when applied in sufficient strength, to temporarily paralyze the ciliary muscle, thus destroying the power of accommodation. This is called the cycloplegic action, and drugs capable of producing it are called *cycloplegics*. Eyes under the influence of a cycloplegic have the power only of focusing for their far-point.

All cycloplegics are mydriatics, as there is a coincident dilatation of the pupil with the paralysis of the accommodation. The best known cycloplegic is atropin. A drug may have a mydriatic action and yet not destroy the accommodation; such a drug, for example, is cocain.

Uses of Cycloplegics.—In cases of refraction they are used for two purposes: (1) to temporarily destroy the power of accommodation, and thus put the eyes in a state of rest while they are being examined; and (2) to give the eyes rest following a period of eye-strain or overwork. The latter effect can, in most instances, be gained by less heroic measures than by destroying the accommodation for weeks and even months. Many different cycloplegics are used for the purpose of estimating refractive errors, and it is important that the effect and duration of several should be well understood in order to apply them intelligently. Cycloplegics are of three kinds: (1) Those having a long effect; (2) those the effect of which lasts but a moderate time; (3) those having a brief effect.

Atropin is strong in its cycloplegic action, and has the longest duration of that action. It was estimated by Jaarama that the

weakest solution with which it is possible to produce a mydriatic effect is 1 : 80,000. The full action of a drop of a 1 per cent. solution on a normal eye takes place in about an hour and a half, and paralysis lasts about four days. Recovery from the effect is not complete until from the tenth to the fifteenth day. The mydriatic effect is quite complete within fifteen minutes after the instillation of one drop of a 1 per cent. solution.

Atropin is carried by the lymph- and blood-streams to the iris, ciliary body, and aqueous, where it acts upon the nerves and ganglia of the muscular structure of the iris and ciliary body. The drug, if carefully used, does not enter the general circulation, as the effect is local, no mydriasis being noticed in the other eye. The aqueous taken from the eye of a rabbit in the conjunctival sac of which a solution of atropin has been instilled will produce a mydriatic effect when dropped in the eye of another rabbit.

Occasionally atropin is not well borne by the conjunctiva, and an inflammation ensues which, on the lids and cheek resembles a dermatitis venenata. If atropin is carelessly used and in too strong solution, symptoms of vertigo, dry throat, flushed face and body, rapid pulse, and possibly delirium may develop. Atropin used for cycloplegic effect is best given in $\frac{1}{2}$ of 1 per cent. solution two or three times a day for a week preliminary to estimation of the refraction. In cases of ciliary spasm it may be necessary to use it in greater strength and for a longer period. In order to avoid any unpleasant symptoms from atropin patients should be cautioned to use the drug with care. Not more than one drop should be used in each eye at a time, and should symptoms develop, the use of the drug should be discontinued, and cold applications applied. Should the symptoms become constitutional, a dose of paregoric may be given, and the patient put to bed in a darkened room.

When instilling the drop, the outer part of the lower lid should be held down, thus making a little trough, in which one drop of the solution is placed. The lid is held in this position for a moment, and then is allowed to spring back into place. An

additional precautionary measure is to have the patient hold the finger tightly pressed over the inner canthus for a few moments after the instillation of the drop. This prevents the solution from flowing into the nose, where it would be easily absorbed by the nasal mucous membrane. More than one drop instilled into the eye will cause an overflow over the cheek and into the mouth, where it is easily absorbed. This accident is more likely to occur in children than in adults.

The usual prescription is as follows:

For Elizabeth Black.

℞. Atropin. sulphatis ..... gr. j;
Aquæ destillatæ ..... ℥ss.
M. Ft. collyrium. Label *poison!*
Sig.—One drop in both eyes three times a day as directed.
℞. Dropper.

M. Jones, M. D.

June 15, 1908.

As the dilated pupils permit the entrance of a great amount of light into the eyes, the effect is often disagreeable, and a double eye-shade or smoked or amber glasses should be perscribed for use during the mydriatic action. Most opticians have a number of pairs of these lenses, which they loan or rent patients for temporary use.

Scopolamin is used as a substitute for atropin when the latter drug produces toxic effects. Scopolamin is, however, more toxic than atropin, and should be used in very weak solution. Certain cases that have an idiosyncrasy toward atropin seem to stand scopolamin very well. The prescription should call for a solution not stronger than 1 : 500, and for children, 1 : 1000 is sufficient.

The effect of scopolamin begins to disappear in about twelve hours after the instillation of a drop of 1 : 500 solution, and complete recovery is noticed by the sixth day. From this it can be seen that the action is less strong than atropin.

Hyoscyamine is considered dangerous by some investigators, and by others thought to be preferable to atropin and duboisin. Risley found that one drop of a 1 : 300 solution paralyzed the accommodation from seventy-seven to one hundred hours.

Complete recovery is noted on about the eighth day. Emmert found that a drop of a 1 : 1000 solution of hyoscyamin is sufficiently strong to paralyze the accommodation. It should be used with caution and in the same strength solution given for scopolamin.

Duboisin acts more promptly and energetically than atropin, and is considered the most powerful mydriatic, but its effect passes off more quickly than atropin. The effect begins to diminish in three days, and complete recovery is noticed in eight days. A drop of a solution of 1 : 3000 is sufficient to paralyze the accommodation of a normal eye for twenty-four hours. This drug is especially toxic in its action, and there is little indication for its use. No greater strength than 1 : 1000 should be used.

Homatropin is the most expensive mydriatic, but its use is very extensive in ophthalmic practice because of its quick action and the fact that its effect passes off quickly. The effect begins to diminish in about ten or twelve hours, and complete recovery is noticed in thirty-six to forty-eight hours, patients being able to do most of their work the next day after the instillation of the drops. Homatropin rarely causes constitutional disturbances, which is an additional point in its favor. Combined with cocain, the mydriatic and cycloplegic effect is excellent. Solutions of 1 : 100 or 1 : 50 are usually used. An excellent prescription is as follows:

For Elizabeth Black.

℞. Homatropin. hydrobromatis ..... gr. ss;
Cocainæ muriatis..... gr. ss;
Aquæ destillatæ. ..... ♏xl.
M. Ft. collyrium. Label *poison!*
Sig.—One drop in both eyes every ten minutes for the hour preceding the office appointment.

M. Jones, M. D.

June 15, 1908.

Cocain is frequently used for its mydriatic effect when the fundi or media are to be examined. Two instillations of a 4 per cent. solution are sufficient to produce good mydriatic effect. The advantage of this drug over homatropin or the

stronger cycloplegics is that accommodation is practically unaffected.

Indications for the Use of a Cycloplegic.—It may be given as a rule, to which there are some exceptions, that all children under fourteen years of age manifesting a hypermetropia or a compound hypermetropic astigmatism should be refracted only under the influence of atropin cycloplegia. In these children the ciliary muscle is very active and well developed, and for this reason homatropin will not sufficiently paralyze the accommodation. Children can better afford the time necessary for an atropin examination than adults, aside from the fact that the action of the stronger drug is more certain. Children complaining of asthenopic symptoms and manifesting a low grade of mixed or myopic astigmatism should also be given atropin preliminary to refraction, as this is one of the most difficult errors of refraction to measure accurately, and its proper correction means much to the patient.

If, on the contrary, the manifest error is a well-marked myopia or compound myopic astigmatism, homatropin is sufficiently strong to produce good cycloplegic effect. In children manifesting a myopia of noticeable amount the accommodation is sluggish and the ciliary muscle underdeveloped. Should the objective and subjective tests following homatropin cycloplegia be unsatisfactory, atropin should be at once prescribed, and the estimation of the refraction delayed until cycloplegic effect is established.

A student in the higher schools and colleges, a clerk, a matron, an active business or professional man, all require some cycloplegic which will incapacitate them the least. They also have a less active accommodation than children, and for them homatropin is not only sufficient, but practically necessary. There are few patients over sixteen years of age whose eyes will not respond perfectly to homatropin, although in some instances a few more drops than the usual number are necessary.

Ciliary spasm always requires the use of atropin, and usually in 1 per cent. strength, no matter what the age of the

patient. These cases are almost always seen in young people, however.

Atropin and homatropin are the most commonly used cycloplegics. In fact, it is unnecessary to use other drugs unless there is some idiosyncrasy toward atropin. As homatropin has very little toxic action, substitutes for this drug are rarely necessary.

It is undoubtedly true that many, if not the majority, of patients can be successfully and correctly refracted without the use of cycloplegics. This is especially true after the age of thirty-five, but many younger patients, who are keen and accurate observers, can be tested with subsequent satisfaction to the physician and patient. It is wise in every instance, except in young children, to make a preliminary test before a cycloplegic is ordered. This test may give a result satisfactory enough to warrant a second or verification test without using a cycloplegic. If the second test agrees with the first test, the physician can be reasonably certain of his results, and no cycloplegic will be necessary.

Myopia and mixed and compound myopic astigmatism need more careful estimation of the refractive error than the hypermetropic conditions, for myopia may be looked upon more as a diseased condition than hypermetropia, and, as a consequence, has more tendency to increase. The low grades of error frequently cause more symptoms than the higher grades, and need careful estimation. No definite rules can be laid down, as the circumstances, occupation, mentality, refractive condition, etc., differ with each patient. The few suggestions above mentioned may give an idea of the problems which only a large experience can solve.

Contraindications to the Use of Mydriatics.—Mydriatics should not be used where there is a tendency toward, or a suspicion of, glaucoma. Corneæ less than 10.5 mm. in diameter are supposed to have a certain tendency toward glaucoma, which a mydriatic will only aggravate. A careful history should be elicited, the cornea measured, if small, and the tension taken

in all cases before prescribing a mydriatic for use at the patient's home. Glaucoma is practically never seen in myopic eyes, so there need be no fear in using mydriatics in these cases.

Nursing women should not be given mydriatics, especially the stronger ones. These women are usually susceptible to these drugs, aside from the fact that they may diminish the secretion of the mammary glands.

It is usually stated that the use of mydriatics for the estimation of refraction is dangerous after the age of forty. It is true that their action is rarely required because of the marked decrease in the power of accommodation, but in certain difficult and obstinate cases they can be used cautiously at any age. The amount of the drug used is usually much less than in younger people. Many patients would suffer greatly from a badly corrected refractive error if the "no mydriatics over forty" rule was strictly observed. Homatropin, in 1 per cent. solution, dropped in both eyes four times at intervals of fifteen minutes, is sufficient to get good mydriatic and cycloplegic effect in presbyopic cases.

Cycloplegia and Ciliary Spasm.—At this point it will not be out of order to describe two conditions for the relief of which the oculist is usually consulted. One condition is cycloplegia, or accommodative weakness; the other is ciliary spasm.

Cycloplegia is a paresis or paralysis of the ciliary muscle, and may be either binocular or monocular. Mydriasis is usually coincident with the cycloplegia, and when they occur together, the condition is called *ophthalmoplegia interna.* The ciliary muscle and sphincter of the iris are supplied by branches of the third cranial nerve.

Etiology.—Temporary paralysis may be due to the instillation of a cycloplegic into the conjunctival cavity of an eye, or by means of internal administration of a cycloplegic. The cases of local action are largely of accidental origin, and may be directly or indirectly due to plasters, ointments, liniments, etc., as well as eye-drops.

Other causes are diphtheria, tonsillitis, influenza, Bright's

disease, rheumatism, typhoid fever, malaria, and other severe diseases, in which case the cycloplegia is usually binocular. Non-penetrating injuries of the eye, such as may be received by a blow, cause monocular cycloplegia. Some cases are of intracranial origin, as brain tumors, syphilis, and meningitis, while in some cases the cause is unknown.

Symptoms.—Lack of accommodation or diminished accommodation is the most marked symptom and the one most noticeable to the patient. The dilated pupil is usually coincident, and this causes photophobia in that it permits of the entrance of an increased amount of light into the eye.

The hypermetropic eye has poor distant and near vision. If the refractive error is corrected, the distant vision will be good, but the near vision will still be poor or absent. The myopic eye has good vision at its far-point only, but with the refractive error corrected, the distant vision is good and the near vision poor or absent.

Treatment.—If the condition is due to the local action of cycloplegics, there is little to do other than to protect the eyes from strong light, and wait until the effect of the drug wears off. The patient should be told that the condition will be transitory, and the cause should be explained. It is useless, in these cases, to instill miotics, as their effect is but temporary, and they may even cause discomfort and irritation. This is especially true if eserin is applied locally for its miotic effect. In any case of cycloplegia smoked or amber lenses should be worn if the photophobia is annoying.

Many cases of cycloplegia are due to diphtheria or other severe throat inflammation, frequently associated with paralysis or paresis of the pharyngeal muscles, rendering deglutition difficult. In these cases the refractive error should be corrected and the glasses worn constantly, and the addition of +3.00 or +4.00 spheric given for near use, to make up for the lack of accommodation. In addition to the local treatment the patient should be given suitable tonics, and plenty of exercise in the open air should be encouraged. Cycloplegia due to

other exhausting diseases is treated in the manner outlined above.

Syphilitic cases should receive mercury and potassium iodid. Both these drugs should be given in liberal doses; large doses of iodid of potassium are, as a rule, better borne than smaller doses, and do more effective work. Mercury is best given in the form of inunctions, although many authorities prefer giving this drug by the mouth. If the latter method is preferred, the protiodid, in doses of $\frac{1}{8}$ to $\frac{1}{2}$ a grain three times a day, will be found to be most effective.

Traumatic cases frequently require no treatment, although some never recover. Pilocarpin used locally as a collyrium in 1 per cent. solution is frequently of benefit in this class of cases. The drug should not be used for a longer period than two weeks, without an interval in which its use is discontinued.

Prognosis depends upon the cause. Cases due to debilitating disease have a good prognosis, as a rule. Syphilitic cases usually respond quite well to antisyphilitic treatment. Traumatic cases usually recover. Cases due to intracranial disease have a more guarded prognosis.

Ciliary Spasm.—This condition is directly opposite to the one just described. The condition may occur in but one eye, but true ciliary spasm is usually binocular. Two forms are seen: (1) *Clonic spasm*, in which the condition is temporary, and passes off after the eyes have been rested, not to reappear for several hours or even days; and (2) *tonic spasm*, which is a continuous contraction of the ciliary muscle and sphincter of the iris. The use of the eyes in the latter condition is accompanied with marked discomfort.

Etiology.—Clonic spasm may occur as a symptom of "eye-strain" or beginning presbyopia. It occurs in the low grades of refractive error, especially if the eyes are used under faulty conditions. Tonic spasm is seen usually in young hypermetropes, or as a manifestation of hysteria or neurasthenia. Certain cases of irregular tonic spasm are undoubtedly due to nasal

or postnasal irritation, and will be permanently relieved only by suitable treatment applied to the cause.

Symptoms.—Tonic spasm gives rise to a condition of pseudo-myopia, the patient frequently complaining of no other symptom than short-sightedness. Usually, however, there are accompanying headache and ocular pain. Theater headache, sight-seer's headache, shopper's headache, and train headache are names frequently applied to ciliary spasm. Pain in the head and eyes may frequently be very severe.

Treatment.—As the cause is usually due to ametropia, the eyes should be put under the influence of atropin or one of the other strong cycloplegics. The patient should wear smoked or amber glasses constantly, and all use of the eyes must be given up as far as possible. After ten days or two weeks the refraction should be estimated and suitable correction worn constantly. Should the symptoms later partially recur, a drop of a 1 : 1000 or 1 : 500 solution of atropin should be instilled into both eyes at night. This treatment, combined with the glasses and cautious use of the eyes, will permanently cure most cases. Tonics or sedatives suitable to the individual case should be given with the local treatment.

Muscular insufficiencies should be carefully looked for and relieved by removing the cause or other suitable treatment. As many of these cases are nasal in origin, the nose should be carefully examined in every instance, and if a pathologic condition is found, the case should be referred to the rhinologist for treatment.

CHAPTER VI

THE METHODS OF REFRACTION

EVERY examination for the estimation of the refractive condition of a patient's eyes should be undertaken systematically, and a careful record of the results of such an examination should be kept in a case-book or on case cards, suitable for filing in a card-index. The tests to be made are both subjective and objective, the subjective tests usually being made first.

SUBJECTIVE TESTS

The patient is seated at the trial-case, 5 meters or more in front of a well-illuminated test-card, as described in a previous

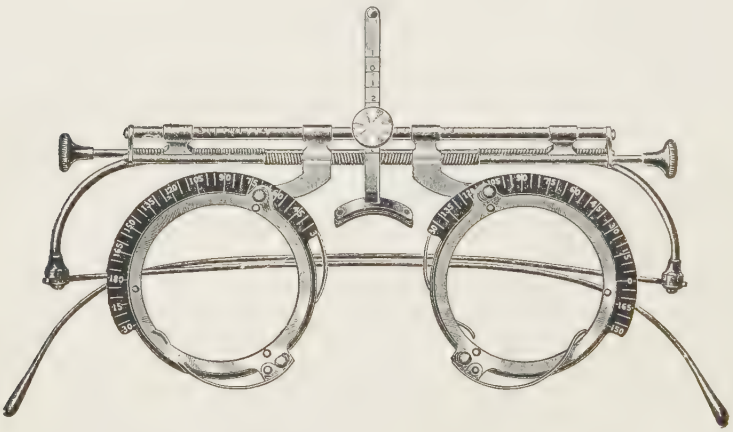


Fig. 53.—The trial frame.

chapter. The trial-frame (Fig. 53) is accurately adjusted, so that the center of the rims for holding the lenses corresponds exactly with the pupil when the eyes are focused for distance. It is of the utmost importance that a proper adjustment of the

trial-frames should be made in every case in order that the best effect of the correcting lenses will be obtained.

After the frames have been adjusted in a satisfactory manner, a shield is placed before the left eye and the patient asked to read the smallest letters he is able to see on the test-card. The acuteness of vision is noted and recorded, thus: V. O. D. = 20/30. Regardless of the visual acuity, a +0.50 sph. is then placed in the trial-frame before the right eye and the effect on the vision noted. If the vision is unchanged or made better, the strength of the convex spherics is increased until the vision through the glass is made worse —"blurred," the patient usually says. The highest convex sphere which gave equal or better vision than the unrefracted eye is then replaced in the trial-frame and the result is recorded. This, for example, may be as follows: V. O. D. = 20/30 + 1.50 sph. = 20/30+. In this instance we are certain that we have to deal with a hypermetropic condition, at least, although it is probably coincident with some hypermetropic astigmatism. If, on the contrary, the +0.50 sph. diminished the vision, a −0.50 sph. should be placed before the eye in its place, and the test continued with concave spheres in the same way as described for convex spheres. The weakest concave sphere giving best vision is then placed in the trial-frame and the result recorded. This may be, for example, V. O. D. = 20/100 − 4.00 sph. = 20/30. Here we are certain that we have to deal with a myopic condition, although it is probably coincident with some astigmatism.

The objective tests just described have given us a rough idea of the manifest hypermetropia and myopia respectively.

The subjective test for astigmatism is made after the manifest spheric correction has been determined. For this purpose the distant vision of the patient is blurred, *i. e.*, the eye to be tested is put in a condition of myopia. In hypermetropic subjects this is done by placing before the eye to be tested a convex spheric lens 1 D. or more stronger than that which corrects the manifest hypermetropia. Should the manifest hypermetropia of an eye be 1.50 D., a + 2.50 sph. is placed before the

eye, when the test-letters will appear blurred. The myopic eye is prepared for this test by reducing the concave sphere, which corrects the manifest myopia by 1 D. or more. For example, the manifest myopia of an eye may be 6.00 D.; the astigmatic test is made with a −4.50 sph. or a −5.00 sph. before the eye.

The axis of the astigmatism, and to a fairly accurate degree the amount, is determined by having the patient look at the astigmatic chart with the blurred eye. The best chart for this purpose is one similar to Fig. 54, which has black lines radiating from a center, each separated by 10-degree intervals. The

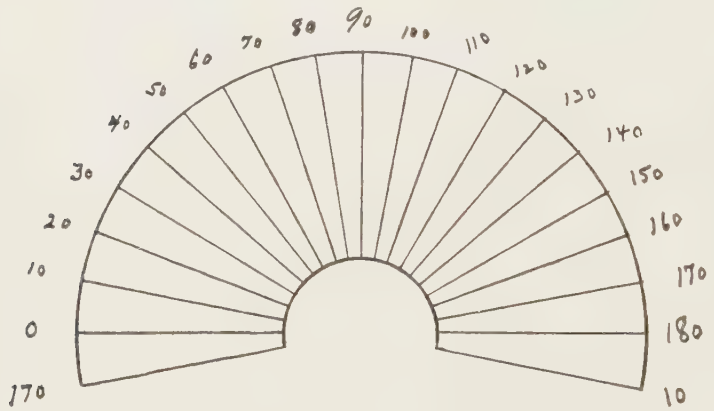


Fig. 54.—Astigmatic chart No 1.

patient having astigmatism will see one, two, or three of these lines plainer than the others. Should the line marked 100 stand out most prominently, this will be the non-astigmatic axis if the condition is hypermetropia, and the astigmatic axis if the condition is myopia. Should lines marked 100 and 110 be equally distinct, the axis of the correcting lens would be between the two, or 105, if the condition was hypermetropia, and at right angles to this if myopia. An astigmatic card, the lines of which are separated by 10-degree intervals, is preferable to either a 5-degree or a 15-degree separation, for the reason that experience has shown it to be more accurate. After the axis is

determined, the second chart (Fig. 55) is then placed before the patient, and one set of fine lines rotated to the axis seen most clearly on chart No. 1. This will make the fine lines running in the axis—105, for instance—plainer than the fine lines running at right angles to them. These lines are made equally clear by placing concave cylinders of increasing strength before the eye in the axis at right angle to the axis of the plain lines, until the desired effect is obtained. The strength

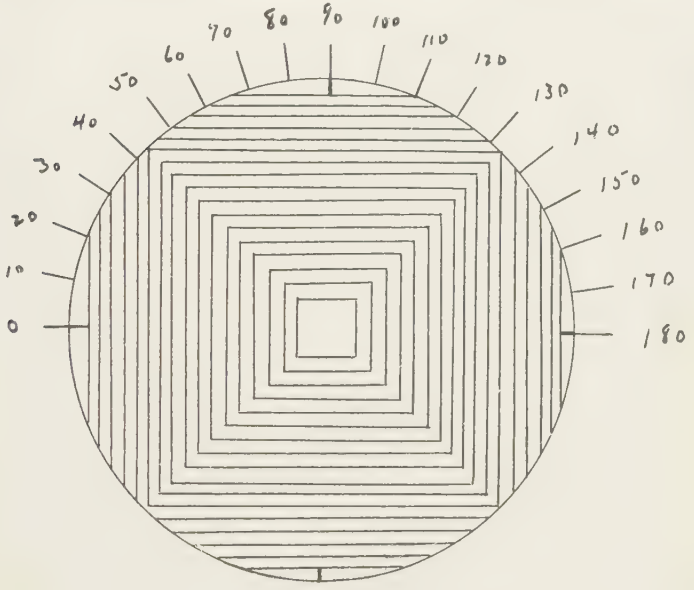


Fig. 55.—Astigmatic chart No. 2.

of the concave cylinder necessary to make the lines appear alike is equivalent to the manifest astigmatic error, and the combination with the sphere correcting the manifest hypermetropia or myopia should give normal vision. If this is not so, the subjective test has been faulty or the refracting media or retina of the eye are at fault. These subjective tests will be more fully described in the following chapters.

After the second eye is refracted in the manner described above, the patient is placed in a dark-room, or the room is

darkened, and the shadow-test is made with the correcting lenses still in the trial-frame. Should the refraction be accurate or nearly so, the retinoscope will show a round, central light area, which moves with equal rapidity in all directions, and which is neutralized with a +1.00 sphere. Should the shadow be other than that which is, with practice, soon recognized as normal, the refraction has been at fault and the test will have to be made again, probably under the influence of a mydriatic. If all tests agree and the vision with the correcting lenses is normal or better, a verification test may be made without using a mydriatic.

OBJECTIVE TESTS

Retinoscopy. -This method of estimating the refraction of the eye is frequently called the shadow-test, and the results are determined by reflecting rays of light into the eye from a plane or concave mirror, and neutralizing the movement which the retinal illumination makes when the mirror is rotated. This moving light area is neutralized by suitable lenses in a manner soon to be described.

Mirrors.—As has been previously suggested, the examiner should become accustomed to one kind of mirror, and this kind should be adhered to. The concave mirror causes the light area to move in the opposite direction to that which is observed when the plane mirror is rotated. As the plane mirror gives the most accurate results and is most generally used, the reader will understand that all subsequent mention of the retinoscope will refer to the plane mirror.

Retinoscopy is practically without value, except as an additional verification test, unless the eyes are under the influence of a mydriatic. If a mydriatic is not used, the accommodation will so change the appearance of the retinal illumination as to render the test inaccurate. Another advantage is the large pupil, which enables the observer to see a large, well-defined light area, the slightest movement of which can be readily detected. The retinoscope may be used without a mydriatic simply to ascertain the character of the refractive error, but even

this is unreliable, except in the high grades of hypermetropia and myopia.

The advantages of retinoscopy are evident. The test is purely objective, and accurate results may be obtained without the aid of the patient, which is of great value in children, the illiterate, and in eyes the visual acuity of which is greatly defective. With practice the correction of the refractive error is obtained quickly and accurately, and the character of the refractive error is determined at a glance.

The examiner should wear his correcting lenses, if such are necessary, and his visual acuity should be normal—preferably, above normal. The physician whose visual acuity is below normal with correcting lenses should not attempt the practice of ophthalmology.

The patient should be seated near the adjustable bracket supplied with an Argand burner, over which is placed a Thorington chimney (Fig. 35). This light may be placed near the retinoscope, or just at the side of the patient's head. The distance of the light from the mirror will not alter the results of the test. The examining room should be darkened, or a special dark-room should be used.

The examiner should be seated at approximately 1 meter's distance from the patient. Rays of light emanating from the retinoscope held 1 meter before the patient's eye will come to a focus on the retina of that eye if the eye is emmetropia, or the refractive error of the patient is corrected, provided a + 1.00 spheric lens is placed before the eye or over the correcting lens. For this reason −1.00 is always added to the results obtained by neutralizing the shadow. This will be explained more in detail later.

The retinoscopic mirror should be held before the eye of the examiner in such a manner that his eye is immediately behind the sight-hole; the patient should direct the eye to be tested toward the forehead of the examiner. The examiner will then see the pupillary reflex, which is a red glow the size of the pupil. The variation in the appearance of the reflex is due to

the degree of the refractive error; the amount of pigment in the fundus, being light in blondes and dark or dull in brunettes; and the condition of the different refractive media.

The retinal illumination corresponds to the portion of the retina which receives the rays of light reflected from the mirror. The retinal illumination is also called the light area or the image.

The shadow is the non-illuminated portion of the retina which immediately surrounds the light area (Fig. 56). The shadow and light area are in contact, and if the illumination changes place by movement of the mirror, the shadow will move also, this being called the movement of the shadow. If the mirror is rotated through the two principal meridians of the eye, the examiner will observe the form, the direction, and the rapidity of motion of the retinal illumination. In rotating the mirror the

Fig. 56.—Diagrammatic representation of the retinoscopic shadow in hypermetropia and myopia.

movement needs to be but slight—the force of the reflected light should be directed toward the center of the cornea.

The Point of Reversal.—To find this is the principle of examination with the retinoscope. If the retinal illumination moves with the direction of the mirror in both the horizontal and vertical meridians of the eye, and this movement is stopped when a +1.00 sph. is placed before the eye, the eye is at the point of reversal. At this point the shadow disappears and the movement of the retinal illumination ceases. If you now add −1.00 to the lens, neutralizing the movement, to allow for the 1 meter's distance the observer is seated from the patient, the result is 0, and the eye has no refractive error, or, in other words, is emmetropic.

With the plane mirror, the only one considered in this chapter, the apparent movement of the retinal illumination will be in the same direction as the light on the patient's face as long

as the observer is under the point of reversal, but when the observer is beyond the point of reversal, the retinal illumination will appear to move in the opposite direction to the movement of the mirror and the facial illumination.

The rate of movement of the retinal illumination gives the observer a valuable guide to the refractive condition. The slower the retinal illumination appears to move, the higher the refractive error, and the faster the movement, the lower the refractive error. Difference in the rate of movement in the two principal meridians of the eye indicates astigmatism.

The direction of the movement of the retinal illumination enables the examiner to tell at a glance the character of the refractive error. If the light area moves against the mirror, the condition is myopia; if with the mirror, the condition is hypermetropia. The exceptions to the latter part of the preceding statement are as follows: The retinal illumination moving with the mirror which is neutralized with a +1.00 sph. shows emmetropia, because, as previously stated, −1.00 is always added to the retinoscopic result to allow for the distance of 1 meter between the mirror and patient. If the retinal illumination is neutralized with a +0.50 sph., the refractive condition would be that of a low myopia, *i. e.*, +0.50 sph. + −1.00 = −0.50. A movement against the mirror in one meridian, and with the mirror in the other, indicates a condition of mixed astigmatism, later to be more fully described.

The form of the illumination is also a diagnostic guide. The large round light area which moves with equal rapidity in all directions indicates emmetropia, myopia, or hypermetropia (Fig. 56). A distinct band of light, which moves more slowly in one meridian than the other, indicates astigmatism (Fig. 57). The correcting cylinder is placed in the axis of the band, or it may be said that the axis of the astigmatism is in the meridian of slowest movement.

The Neutralization of the Illumination.—When the light area, seen through the sight-hole of a plane mirror held at the distance of 1 meter from the patient's eye, moves in the direction of the

mirror, a plus lens is necessary to stop all movement. If the light area moves in the opposite direction to the mirror, a minus lens is necessary to stop all movement.

Retinoscopy Applied to Emmetropia or an Eye Made Emmetropic by Correcting Lenses.—A +1.00 sph. placed before such an eye would stop all movement of the retinal illumination. In other words, it would be at the point of reversal, and would show either emmetropia or a perfect correction of the refractive error. In this manner the retinoscopic test is used to verify the results of subjective tests.

Retinoscopy Applied to Hypermetropia.—The light area in this condition moves with the mirror, and the movement is neutralized by placing convex spheres of increasing strength before the eye until all the motion ceases. Should, for example, the point of reversal be obtained by a +5.00 sph., −1.00 is added to give the eye parallel rays of light or focus for infinity. The result would be +4.00 S., or the eye may be said to be hypermetropic 4.00 D.

Retinoscopy in Myopia.—The light area moves against the mirror in this condition in all degrees above 1 D. At 1 meter's distance from the eye the retinal illumination of a patient having 1.00 D. of myopia will be neutralized. Should − 3.00 sph. be required to bring an eye to the point of reversal, the refractive error would be − 3.00 sph. + − 1.00 = − 4.00 sph.

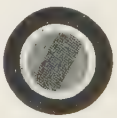


Fig. 57.—Diagrammatic representation of the retinoscopic shadow in hypermetropic astigmatism.

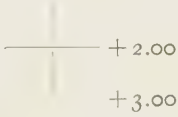
Retinoscopy in Astigmatism.—This form of refractive error is somewhat more difficult to determine accurately than the cases of pure myopia or hypermetropia, but with experience comes more accurate work until astigmatism is no more difficult to estimate than other errors. Cases in which the astigmatism is marked will show a definite band of light (Fig. 57) either

before the spheric correction is placed before the eye, or this band may not be made out until the spheric correction is placed before the eye. In cases of compound myopic astigmatism the light area will move in the opposite direction to the mirror, but the movement will be more rapid in the axis of the light band than at right angles to it. For this reason it will take a lens of greater strength to neutralize the retinal illumination at right angles to the light band than in its axis. For example, the movement may neutralize in horizontal meridian with a −2.00 sph., and in the vertical meridian with a −4.00 sph. This is usually recorded thus:

−1.00 is added, as in every case, and the result is changed to

the lens correcting such an error would be −3.00 sph. ⌓ −2.00 cyl. 180°.

In compound hypermetropic astigmatism the retinal illumination moves with the mirror in both meridians of the eye, but more slowly in one meridian than the other. For example, the movement may neutralize with a +2.00 sph. in the vertical meridian and a +3.00 sph. in the horizontal; thus:



−1.00 added the correcting lens would be +1.00 sph. ⌓ +1.00 cyl. 90°. In simple myopic and compound myopic astigmatism and in simple hypermetropic and compound hypermetropic astigmatism the difference between the two spheres gives the

amount of the astigmatism, as shown by the examples given above.

Retinoscopy in mixed astigmatism is no more difficult than in compound astigmatism. In this form of refractive error the retinal illumination moves with the mirror in one meridian, and against the mirror in the other. The lens correcting such an error will, of necessity, be concave in one meridian and convex in the other. This is more fully described in the chapter on Astigmatism.

Irregular astigmatism is readily diagnosed with the retinoscope, but it, at best, is but a rough guide in estimating the amount and character of the refractive error. This form of

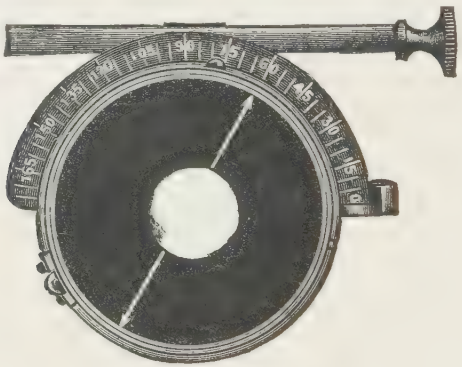


Fig. 58.—The axonometer.

astigmatism is best refracted by subjective tests, more fully described later. Irregular astigmatism of the lenticular variety is characterized by faint striæ, which radiate from the center like spokes of a wheel.

There is a condition of the retinal illumination, known as the *scissors movement*, which is very confusing. The astigmatic light area is made up of two bands separated slightly, which are usually seen in the horizontal meridian. When the mirror is tilted in the vertical meridian, the two bands of light seem to approach each other and usually become one; the lower one moves up and the upper one moves down. To neutralize an

eye having such a shadow the horizontal meridian is neutralized first, and after this point has been reached the sphere (usually +) neutralizing the horizontal meridian is left in the eye, and the vertical meridian neutralized by adding minus cylinders, axis horizontal, of increasing strength until no motion of the light area is made out.

The axonometer (Fig. 58) is a useful guide in determining accurately the axis in which the cylinder correcting the astigmatism is to be placed. As most cases of astigmatism are off axis (*i. e.*, not exactly vertical or horizontal), the value of such a simple aid is readily seen. The arrow is rotated in the trial-frame until it coincides with the axis of the astigmatic light band. The cylinder is later put in at a corresponding axis.

The ophthalmoscope as a means of determining the refractive error will be considered in a special chapter on that instrument.

The ophthalmometer, as a method of estimating the amount and axis of astigmatism, is considered in the chapter on Astigmatism and the chapter on Aphakia.

CHAPTER VII

THE OPHTHALMOSCOPE

The ophthalmoscope may be defined as an instrument for examining the fundus and media of an eye. The modern ophthalmoscope is arranged with a set of concave and convex

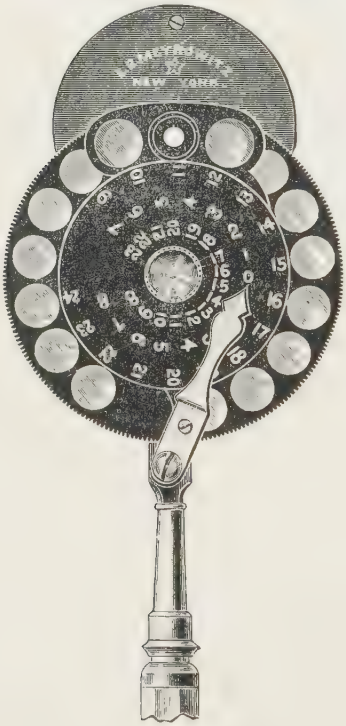


Fig. 59.—Roth's ophthalmoscope Lens side.

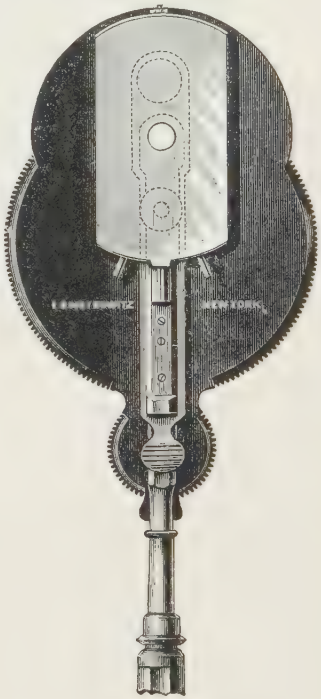


Fig. 60.—Roth's ophthalmoscope. Mirror side.

spheres, which can be rotated behind the sight-hole, and by means of the lenses the refraction of the eye determined (Fig. 59). This method of refraction is uncertain and has, in recent

years, become practically obsolete, the lenses of the ophthalmoscope being now used only that a clear view of the fundus or media may be obtained. Besides the lenses, the ophthalmoscope is provided with a mirror for reflecting rays of light into the eye (Fig. 60). This mirror is almost always concave, and when the ophthalmoscope is used as a retinoscope for diagnosing the refractive error of an eye, it must be remembered that the retinal illumination moves in the opposite direction to that seen with the plane mirror. The pupillary reflex will appear much the same as that seen with the retinoscope, but it will be more brilliant, and, as a consequence, the convex is superior to the plane mirror for examining the condition of the media. There are many ophthalmoscopes on the market, the Loring (Fig. 61) being an excellent instrument for the beginner, and, indeed, for the advanced student. The Roth (Fig. 60) instrument is somewhat better adapted for finer work, and is of a type that will be used after the physician has become more expert in the art of using the ophthalmoscope.

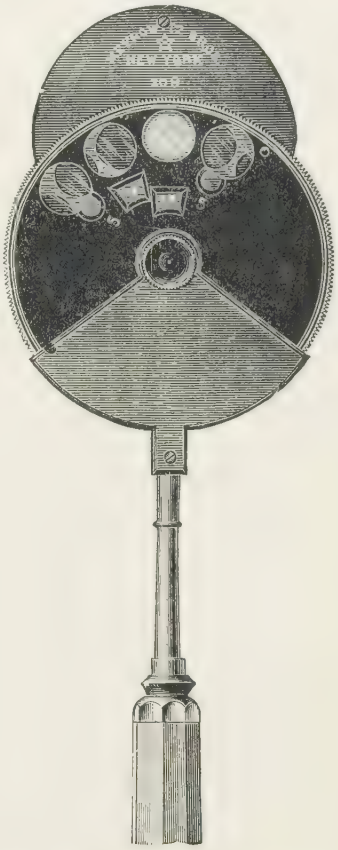


Fig. 61.—The Loring ophthalmoscope.

The pupil of a healthy eye appears black to the observer, due to the fact that ordinarily the eye of the observer does not intercept rays of light returning from the eye observed. As rays of light entering an eye are returned to their source, the

observer must put his eye in the pathway of these returning rays in order to examine the interior of the eye. This is accomplished with the ophthalmoscope or retinoscope, by means of the small sight-hole in the center of the mirror.

The lenses of the ophthalmoscope usually range from +1 to +23, and from −1 to −24. The Roth instrument has an additional lens, +0.50, which can be used for finer adjustments.

The ophthalmoscope is used in two ways or methods—the direct and the indirect.

Fig. 62.—Method of ophthalmoscopic examination (direct).

The direct method (Fig. 62) is somewhat more difficult to learn than the indirect, as the observer has much trouble in relaxing his accommodation. This comes with practice, but in younger people there is practically never a perfect relaxation.

The room should be darkened, as described in the previous chapter, or a special dark-room should be provided. The light used for retinoscopy is suitable for ophthalmoscopic work, and should preferably be from an Argand burner over which a Thorington chimney is placed. The iris-diaphragm of this chimney should be wide open. The light should be placed at

the side and slightly behind the patient, on a line with the eye to be examined. For a thorough and complete examination of the fundus and media a mydriatic should be used, although with much practice the examiner is able to make out almost any change in the eye-ground and media without using a mydriatic. In many cases, though, it is impossible to study accurately the region of the macula without a mydriatic, because of the extreme contraction of the pupil when the patient looks directly at the mirror.

The patient is seated in a chair, which can be raised or lowered, and should be told to look at a distance beyond the ear of the observer corresponding to the eye examined. If the right eye is being examined, the patient looks at some distant object beyond the right ear of the observer. The reverse is true for the left eye.

The observer, with his own ametropia corrected if present, shall seat himself on the side of the patient corresponding to the eye to be examined. The ophthalmoscope is held in the right hand in examining the right eye, and in the left hand in examining the left eye. The observer's eye should be on a line with the patient's, or slightly above this line. Both eyes of the observer and patient should be kept wide open, and the eyes focused for distance.

With the ophthalmoscope held close to the eye, the observer approaches slowly the eye to be examined. If the patient looks in the direction previously indicated, the optic disc will be in the center of the field, and as this is the landmark of the fundus most easily seen, it is usually searched for first. It seems hardly necessary to mention that the mirror of the ophthalmoscope should be tilted toward the light.

The first thing noticed is the red reflex, in which may be seen a white glow. As the observer approaches the eye he will notice the condition of the media. Any opacity in the cornea, aqueous, lens, or vitreous will appear black. The location of such opacities in relation to the visual axis and their apparent situation should be carefully noted. The details of the optic

disc begin to be made out as the ophthalmoscope nears the eye under examination, and when in focus, is seen to be of a pinkish-white color, in contrast to the darker red of the surrounding retina.

The shape of the disc varies, but is usually slightly more oval than round. The appearance, of course, is much altered by various refractive conditions, especially astigmatism. The branches of the central artery of the retina are seen entering the eye, usually to the nasal side of the center of the optic disc. On the temporal side of the arteries are seen one or two trunks of the retinal vein. The veins are normally somewhat larger than the arteries, and are distinctly darker in color. The center of the disc shows a slight depression, known as the physiologic cupping, which varies greatly in the normal eye, and which must not be confused with the cupping caused by disease. The bottom of this cup frequently shows a small striped gray area, which is the membrana cribrosa.

There are usually two fairly well-marked rings surrounding the disc: the inner ring is chalk white, and is called the scleral ring; the outer ring contains more or less pigment, and is called the choroidal ring. The latter ring is more often incomplete than complete; when incomplete, it is spoken of as a choroidal crescent. The retinal vessels are named the upper nasal vein and artery; the upper temporal vein and artery; the lower nasal vein and artery; and the lower nasal vein and artery.

The retina is perfectly transparent in health and is not seen. The macular region occupies the posterior pole of the eye, and is devoid of large blood-vessels. At the center of the macular region, corresponding to the visual axis, is the fovea centralis (yellow spot), which is the only part of the retina having acute vision.

The fovea is situated about two disc diameters to the temporal side of the optic nerve. It is about 2 mm. in diameter, and is of a more brilliant color than the surrounding retina. It may even be very slightly reddish, and is not infrequently surrounded by a faint pigment ring or zone.

The choroid is the coat of the eye seen through the transparent retina. The individual choroidal vessels are not seen, except in the albino. This coat appears almost uniformly light red, over which the retinal vessels are easily made out. In dark-complexioned people pigment-streaks are frequently seen.

All the details of the fundus above described should be plainly made out through the sight-hole of the ophthalmoscope, behind which no lens has been placed, provided the observer's eye is in a condition of emmetropia and the patient's eye is emmetropic or nearly so. It must be understood that the accommodation of both observer and patient is perfectly relaxed. Under these conditions the retinæ of the observer and patient may be considered as conjugate foci.

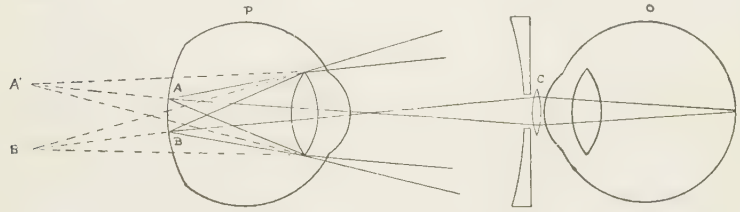


Fig. 63.—*O* is the eye of the observer; *P*, the eye of the patient; *C*, the convex lens rotated behind the sight-hole of the ophthalmoscope; *A* and *B* represent the extremities of the part of the fundus seen by the observer from which rays of light diverge. Projected backward these form an erect magnified image *A'*, *B'*.

In hypermetropia the rays of light reflected into the eye from the convex mirror of the ophthalmoscope are passed out of the eye as divergent rays, and these must be made parallel in order to come to a focus on the retina of the observer (Fig. 63). This is accomplished by rotating convex lenses of increasing strength behind the sight-hole of the ophthalmoscope until the retina of the patient is plainly seen. If the observer is emmetropic or made so by wearing suitable correcting lenses, and his accommodation and the patient's are perfectly relaxed, the strength of the convex lens (C, Fig. 63) necessary to see the retina clearly represents the amount of the patient's hypermetropia.

In myopia the rays of light passing out of the eye are convergent, and, in order that these rays may come to a focus on the retina of the observer, concave lenses of increasing strength must be rotated behind the sight-hole of the ophthalmoscope until the retina of the patient is plainly seen (Fig. 64). The strength of the concave lens necessary to accomplish this measures the amount of the myopia.

In astigmatism the rays of light passing out of the eye are reflected unevenly, and the usual method of determining the amount and character of the astigmatism is to find the glass which renders the vertical vessels and lateral sides of the disc distinct, and then find the lens with which the vessels running

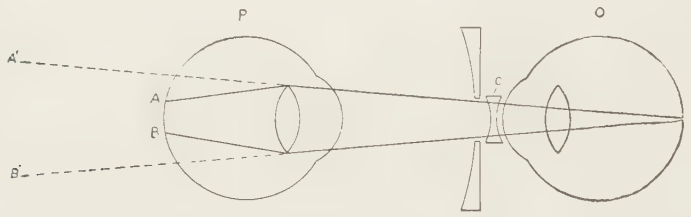


Fig. 64.—*O*, Observer's eye; *P*, patient's eye; *A*, *B*, extremities of fundus seen by the observer, from which emanate rays which pass out of the eye convergently and need the concave lens (*C*) behind the sight-hole of the ophthalmoscope to focus them on the observer's retina. *A'*, *B'* is erect enlarged image projected backward.

horizontally are most distinctly seen. If, for example, the vertical vessels are distinctly seen without a lens behind the sight-hole, this shows that the horizontal meridian of that eye is emmetropic; if, in this same eye, a convex or a concave lens is necessary to see the horizontal vessels distinctly, the vertical meridian is hypermetropic or myopic respectively. The refractive error of such a case would be one of simple hypermetropic or myopic astigmatism.

In compound hypermetropic astigmatism convex lenses are necessary to see both meridians distinctly, but one meridian requires a stronger lens than the other. The difference between the two lenses represents the astigmatism. The same is true

in refracting a case of compound myopic astigmatism with concave lenses.

If the vertical meridian is seen plainly with a convex lens and the horizontal meridian with a concave lens, the case is one of mixed astigmatism, and the astigmatism is equal to the sum of the two lenses.

Estimation of the refraction with the ophthalmoscope is very little practised at the present day. More simple methods than this are readily at hand, and more accurate in their results. The lenses of the ophthalmoscope are used simply to make the fundus of the eye distinct, no matter what the refractive error. The fundus of highly myopic eyes is not easily seen by the direct method, but the details of the fundus may be seen through the unrefracted sight-hole if the ophthalmoscope is held at some distance from the patient's eye, or the indirect method is relied upon.

In inflammation of the optic nerve (choked disc) it is frequently of value to refract the amount of the swelling. This is done by focusing the uninvolved retina as near the disc as possible, and then focusing on the tip of the swelling. This swelling may frequently reach 7 or 8 D.

If the observer does not use his own correction and wishes to estimate the refractive error by means of the ophthalmoscope, he must always make allowance for this uncorrected error in arriving at his conclusions. If this error is 2 D. of hypermetropia and it requires a +3 sph. to see the fundus clearly, the amount of the patient's hypermetropia is but 1 D.

It is advisable to again repeat that this method of determining refraction is inaccurate except after a very large experience, and should not be relied upon by the beginner.

Size of the Image Seen by the Direct Method.—The image seen by the direct method is virtual, erect, and enlarged. The optic disc of an emmetropic eye appears to be about 25 mm. in diameter, and about 25 cm. in front of the observer's eye. The magnification by the direct method is about sixteen times larger than actual size.

The indirect method (Fig. 65) differs from the direct method in that the observer does not sit so near the patient, and the view of the fundus is obtained by means of a large convex lens, usually 16 D. in strength (Fig. 66). As in the direct

Fig. 65.—Method of ophthalmoscopic examination (indirect).

method, the best view is obtained if the pupil is first dilated with a mydriatic. It is necessary to rotate behind the sight-hole of the ophthalmoscope a +3 sph. or a +4 sph. in order to see clearly the retinal picture.

Fig. 66.—The objective lens.

The observer holds the ophthalmoscope in his right hand, and usually uses his right eye in examining both the right and the left eye of the patient. The large lens, called the objective lens, is held in the observer's left hand, about $2\frac{1}{2}$ or 3 inches in front of the eye to be examined. The patient is seated as

described under the direct method, and the light arranged in a similar manner. The media are hastily examined, and the patient is told to turn his eye in such a position that the optic disc occupies the center of the field. It will probably be necessary to move the objective lens back and forth a trifle in order to get good focus, and the observer will have to vary his distance from the patient's eye for the same purpose. The left hand, holding the objective lens, should be steadied by resting the little finger against the patient's temple or cheek.

The indirect method gives an aërial image, formed between the objective lens and the ophthalmoscope. The direct method gives an erect, virtual, and enlarged image; the indirect gives an inverted, real, and less enlarged image than the direct.

The size of the image by the indirect method is about four or five times larger than the real structure. This method will give a larger field than the direct, and, as the image is brighter, fundi not seen by the direct method may be seen fairly well with the indirect. On account of the larger field, this method is, in most cases, more satisfactory with a small pupil than the direct, and also shows at a glance the portions of the fundus requiring more minute study by the direct method.

In cases of high myopia the indirect method is practically the only way in which the fundus details can be made out. The +4 sph. in the ophthalmoscope is used to magnify the image, and at the same time relieves the observer of accommodative effort.

The Luminous Ophthalmoscope (Fig. 67).—De Zeng's instrument was one of the first, if not the first, on the market, and all later models have been patterned after his. The instrument is the ordinary Loring, provided with an electric illuminating attachment. The mirror is circular in form, about 14 mm. in diameter, with a portion of its upper half cut off. The flat top of the mirror is on a level with the lower edge of the sight-hole of the ophthalmoscope. This form of mirror has the disadvantage that the lower portion of the field is cut off. An excellent modification is now made in which the mirror is

U shaped, which obviates this objection to the earlier instruments. The mirror is placed at an angle of about 45 degrees, which reflects rays of light into the eye from the small electric-light bulb carried in the handle of the instrument. Between the lamp and the mirror is placed a strong convex lens, which

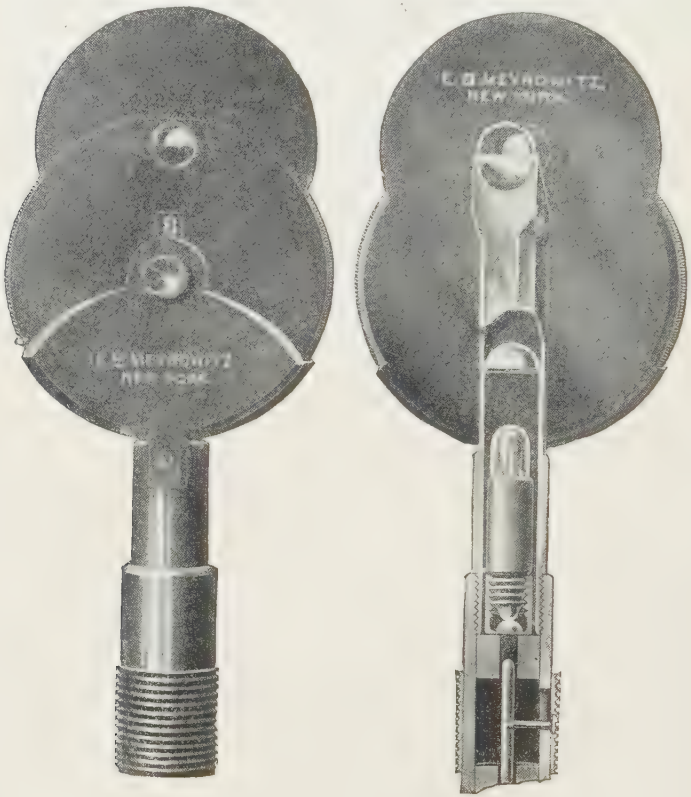


Fig. 67.—Dr. Dennet's electric ophthalmoscope.

converges the rays of light from the electric bulb and makes them more luminous.

The advantages of this instrument are that it may be used for bedside work, and the brilliancy of the illumination enables the instrument to be used in a fairly light room.

CHAPTER VIII

HYPERMETROPIA

Before proceeding to the discussion of the various errors of refraction, it is necessary to describe more fully than has been done the normal or emmetropic eye. An eye is emmetropic when, in a state of rest, parallel rays of light come to a focus on its retina (Fig. 27, E). Such an eye is approximately 23 mm. in length in its anteroposterior axis.

Rays of light emanating from an emmetropic eye are parallel. Consequently an emmetropic eye is, in a state of rest, adapted for infinity. It also is considered a healthy eye, in contrast to a myopic or hypermetropic eye, and is also an eye which does not develop presbyopic symptoms until about forty-five or fifty years of age.

An eye may be considered as emmetropic, no matter what its length, if its refractive apparatus is of just such strength that, in a state of rest, its principal focus coincides exactly with the fovea.

Ametropia.—An ametropic eye is one which, in a state of rest, does not focus parallel rays of light on its retina, and it is the purpose of this chapter to discuss the most frequently seen form of ametropia, namely, hypermetropia.

Hypermetropia.—This condition is frequently called "far-sightedness," but as this term is misleading, it should be given up. The term hypermetropia can be as readily defined, if necessary, as the terms emmetropia, ametropia, etc.

Hypermetropia may be defined as the condition of an eye in which the anteroposterior axis is so short that, in a condition of rest, parallel rays of light come to a focus behind its retina (Fig. 68). The strength of the refractive apparatus of such an

eye is such that its principal focus lies behind the retina. Parallel rays of light entering a hypermetropic eye strike the retina before coming to a focus, and, as a consequence, the visual acuity of such an eye, in a state of rest, is diminished proportionately to the amount of the hypermetropia.

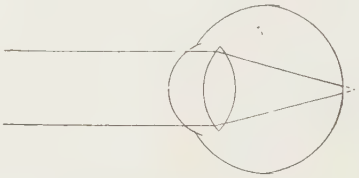


Fig. 68.—The focus of parallel rays of light on the retina of a hypermetropic eye in a state of rest.

A hypermetropic eye can focus convergent rays of light on its retina only in a state of rest, and, therefore, such an eye emits divergent rays of light.

As convergent rays are not found in nature, but can be produced only artificially, the hypermetropic eye requires a convex lens to focus parallel (natural) rays of light on its retina (Fig. 69).

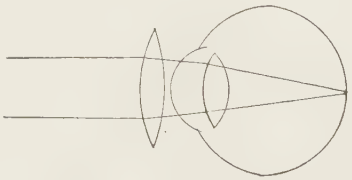


Fig. 69.—Parallel rays of light brought to a focus on the retina of a hypermetropic eye by means of a convex lens placed before the eye.

From the foregoing paragraph it is easy to deduce the fact that the hypermetrope, in order to see clearly at any distance without the use of a convex lens, must use his accommodation constantly. This causes a constant contraction and increase in development of the ciliary muscle. This accommodative effort for distance leaves less power of accommodation for near objects, and consequently the near-point of a hypermetropic eye is farther removed than that of an emmetropic eye for the same age.

The constant contraction of the ciliary muscle frequently causes an irritative condition of the retina and choroid. Presbyopia develops proportionately early in hypermetropic eyes. As but a small proportion of the accommodation can be used constantly, cases of high hypermetropia requiring over 5 D. of accommodative effort to see clearly in the distance rarely use the required amount, and the distant vision of such eyes is poor, and near vision is sustained but a short time, and then with an effort.

Hypermetropia is divided into manifest and latent. Donders divides the manifest hypermetropia into absolute, relative, and facultative.

Absolute hypermetropia is when, by the strongest accommodative effort, distant vision remains indistinct.

Relative hypermetropia is when it is possible to accommodate by squinting (*i. e.*, converging).

Facultative hypermetropia is when objects can be clearly seen with or without convex lenses. A facultative hypermetropia in youth may become absolute as age advances.

Manifest hypermetropia is represented by the strongest convex lens through which an eye can see distinctly in the distance.

Latent hypermetropia is the amount of hypermetropia which an eye retains when the strongest plus lens giving distinct distant vision is placed in front of it. The manifest hypermetropia is brought out by convex lenses when the eye is not under the influence of a cycloplegic. The latent hypermetropia is equal to the difference between the manifest hypermetropia and the full amount of hypermetropia as determined by a cycloplegic examination.

Total hypermetropia is the full amount of hypermetropia as determined by cycloplegic test. It is represented by the strongest plus spheric giving distinct vision.

Causes of Hypermetropia.—The eyes of the new-born are almost invariably hypermetropic—that is, they are short in their anteroposterior axis. This condition is supposed to become

normally emmetropic at about the age of puberty, but the real emmetropic eye is distinctly rare. This is explained by the fact that the length of the eyeball rarely increases in proportion to the strength of its refractive system.

In old age an eye may become hypermetropic from flattening of the lens due to sclerosis.

The removal of the lens, as in cataract extraction, causes a condition of hypermetropia. This condition is also caused by the flattening of the cornea from disease. Another cause is diminution in the index of refraction of the media of the normal eye.

Symptoms.—The chief symptom is undoubtedly headache. The headache is usually frontal, ocular, or temporal, and comes on after use of the eyes. The early morning is free from headache, as the eyes have become rested during the night. The headache is frequently absent on Sunday or other days of rest from near work or concentration of attention. The constant action of the ciliary muscle induces retinal and choroidal irritation, and also various reflex disturbances, such as vomiting, dyspepsia, constipation, hysteria, melancholia, chorea, and other nervous manifestations.

Local ocular inflammation, such as conjunctivitis, blepharitis, hordeola, and chalazia are very frequently the result of hypermetropia, and these conditions are only temporarily relieved by medication. Their permanent relief will not be obtained until a suitable correction of the refractive error is worn constantly. Epiphora is not an uncommon symptom of hypermetropia. On account of the marked activity of the ciliary muscle, sleepiness and drowsiness are commonly noticed after prolonged use of the eyes.

The patient usually complains of headache and blurring of the print, or that "the letters run together" after a varying period of near work. This blur is, of course, due to a relaxation of the accommodation.

Children are frequently sent to the oculist by parents or school-teachers because of supposed myopia. This may be

due to one of two causes—either that the child has ciliary spasm, which is a condition of pseudomyopia (see Chapter V), or the book or paper is instinctively held nearer the eye than normal, in order to obtain a larger retinal image and thus relieve the accommodation. Myopia may be excluded in these cases by the history and the fact that myopia is rare in childhood. The distant vision is usually fairly good. The child has to read slowly, as the image on the retina is a blurred one; this is not necessarily true of ciliary spasm. The shadow-test will show hypermetropia, except in cases of tonic ciliary spasm, in which cases a strong cycloplegic must be used in order to relieve the contraction of the ciliary muscle and show the true condition. All cases of pseudomyopia in children should be tested with a cycloplegic, so that concave lenses will not be prescribed for a hypermetropic eye. Illness, overwork, and nervous strain accentuate all symptoms of hypermetropia.

Signs.—Hypermetropic eyes appear smaller than the normal eye in all dimensions. The iris and lens are apt to be more forward, and the anterior chamber narrow. The pupil is usually smaller than normal because of coincident contraction of the sphincter of the iris with the ciliary muscle. The angle alpha is larger than in the normal eye, and gives the appearance of slight divergence.

Diagnosis.—The diagnosis can usually be inferred from the history of the patient, the presence of blepharitis, conjunctivitis, epiphora, and the frequent appearance of "styes." The small eye is readily detected at a glance. Cases of convergent squint almost always show hypermetropia. Frontal headaches and blurring of vision coming on after use of the eyes are usually caused by hypermetropia. The distant vision is usually good—20/20 or better. These cases with normal vision should not be called emmetropic by the beginner. The diagnosis is accurately determined by means of the retinoscope, the ophthalmoscope, and objective tests later to be described.

Refraction.—The patient is placed at the trial-case, and the trial-frame is accurately adjusted to the eyes, so that the centers

of the trial-lenses will correspond with the center of the pupils. One eye is then covered with a screen. The visual acuity is taken, and convex lenses of increasing strength are placed before the eye until the vision of the smallest line of letters seen by the patient becomes blurred. Should, for example, the lens giving 20/20 or better be a +2.50 sph., a +3.50 sph. is then placed before the eye and the strength gradually reduced by means of weak convex lenses until clear vision is obtained. By this latter method we are frequently able to make the patient accept a stronger convex lens than when we increase the strength from the weaker lenses. The strength of the convex lens giving the best vision measures the amount of the manifest hypermetropia, which in some instances measures the total hypermetropia. In older patients this is more often true than in younger people. The manifest hypermetropia is then determined for the other eye in a similar manner.

The eyes are then examined by retinoscopy, with and without lenses correcting the manifest hypermetropia. If the retinoscope shows the light area moving more or less slowly with the mirror, when the manifest correction is worn, it is evident that all the hypermetropia is uncorrected. Or if the amount of the manifest hypermetropia is less than would be suspected from the severity of the symptoms, it will be necessary to use a cycloplegic. As previously described (Chapter V), a cycloplegic should be used in testing the eyes of all children, and there is none better than atropin, 2 grains to the ounce. In older people the use of a cycloplegic will depend upon the results of the subjective and objective tests at the first examination. No definite rule can be laid down for this: experience alone will enable the physician to do that which is best for the interest of the patient and himself.

Almost invariably, except in people over thirty-five or forty, the subjective test with the test-cards will require a much higher convex lens when the cycloplegic is used than the previous test. This shows the amount of the latent hypermetropia.

If the condition is a true hypermetropia, the subjective test

under a cycloplegic will give a plus spheric lens, which, placed before the eye and examined by retinoscopy, will show a round, even, fairly rapid shadow, which moves in the direction of the mirror. This shadow should be neutralized with a +1.00 sph.

If a cycloplegic is not used, and by objective tests the examiner has estimated the hypermetropia to be 2.00 or 3.00 D., the patient may then be seated near the trial-case and a + 4.00 or even + 5.00 placed before the eye, which is called "fogging" the vision. This glass is gradually weakened with concave spheres, in the manner described above. This test may bring out some of the latent hypermetropia.

If a cycloplegic is used, a record of the retinoscope findings in both meridians of the eye should be kept. Thus:

O. D.	O. S.
+4.00	+4.50
+4.00	+4.50

Adding −1.00, as previously described, the result would be +3.00 sph. for the right eye and +3.50 sph. for the left. If the retinoscopic examination has been accurate, these lenses will give the best visual acuity in the corresponding eye.

If at the first visit it was found in this same case that the best vision was obtained in the right eye with a +1.25 sph., and in the left eye with a +1.50 sph., it is possible that this is the strongest lens the patient will accept. It is, however, the best practice to see the patient after the effect of the cycloplegic has passed off. At this post-mydriatic visit, so called, the physician knows both the manifest and the latent hypermetropia, and this gives him confidence to force stronger lenses. The patient also is usually able to accept with comfort a stronger lens than at the first visit.

It must be remembered that a convex lens of such strength as to blur each eye when tested separately will often give clear vision when both eyes are used together.

If the patient is unable to return for a post-mydriatic visit,

and the eyes have been tested previous to the use of a cycloplegic, a reduction can be made from the total hypermetropia which will seem to the physician right. A greater reduction should be made for patients wearing glasses for the first time than for those who are accustomed to wearing them. If the glass prescribed is of greater strength than the amount of the manifest hypermetropia, the patient must be warned that the glasses at first will be very liable to "blur" for distant vision, but as the eyes adjust themselves and the ciliary muscle relaxes, the distant vision will improve.

There is little doubt that in most every case of refractive error where the patient complains of asthenopic symptoms glasses should be worn constantly. By so doing the eyes are placed in a condition approaching emmetropia, and that which is normal is right. The pernicious habit of prescribing weak convex lenses for distance and stronger convex lenses for near use in patients many years under the presbyopic age should be given up. Patients so treated are made early in life a slave to two pairs of glasses, and are rarely relieved of their symptoms, or at most only in part.

We frequently, however, have patients who are troubled with severe symptoms of hypermetropia who refuse to wear correcting glasses constantly. They should be told the necessity for wearing them all the time,—at least until relieved of their symptoms,—and then, if they will not do so, the physician is not to blame. Fortunately, this type of patient is growing less each year.

If the manifest hypermetropia only is corrected, it will become necessary to change the lenses frequently, which is an annoyance and an unnecessary expense to the patient.

At the risk of too much repetition it must again be stated that the strongest possible sphere must be given which will relieve the symptoms of the patient without too great discomfort following the use of the glasses. Two sets of glasses, one for near and the other for distance, should not be prescribed earlier in life than the development of the presbyopic condition.

CHAPTER IX

MYOPIA

Myopia is that refractive condition of the eye in which the anteroposterior diameter is longer than in the emmetropic eye, and, as a consequence, parallel rays of light come to a focus in front of the retina (Fig. 70, M). This condition is called short-sightedness, because of the fact that distant objects are indistinctly seen and near objects must be held close to the eye. Simple myopia occurs much less frequently than hypermetropia, it being found in about 1.5 per cent. of all eyes.

As parallel rays of light entering a myopic eye come to a

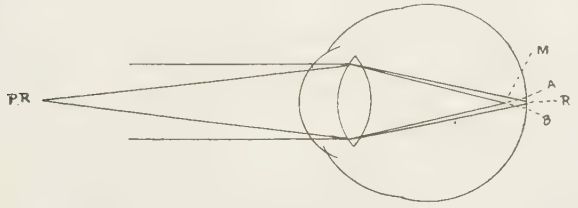


Fig. 70.—Parallel rays focus in front of the retina of a myopic eye (*M*). Rays emanating from the retina of a myopic eye (*R*) focus at *PR*, which is the punctum remotum.

focus in front of the retina, these rays cross and form a diffusion circle on the retina, which gives the "blurred" look to distant objects (Fig. 70, A, B).

Rays of light emanating from the retina of a myopic eye are convergent after passing out of the eye, and come to a focus at some point within infinity. This point is the punctum remotum of the myopic eye (Fig. 70, P, R), as it is the greatest distance at which objects can be seen distinctly by the myopic eye. The nearer this point to the eye, the greater the degree of myopia, and

the further away the punctum remotum, the less the amount of myopia.

As parallel rays of light cannot focus on the retina of a myopic eye, but focus in front of it, it becomes necessary to make parallel rays of light divergent before entering the eye in order that they may come to a focus on the retina. This is accomplished by means of concave spheres (Fig. 71).

The near-point of a myopic eye is nearer the eye than the near-point of an emmetropic eye. Because of this fact the accommodation is called less into play for near vision (never for distant vision), and the ciliary muscle is much less developed than in hypermetropia, and considerably less developed than in emmetropia. Patients having their myopia fully corrected by

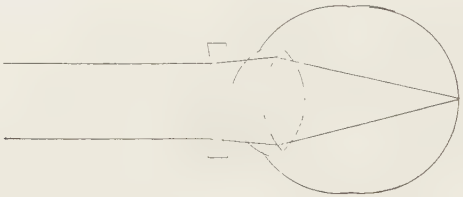


Fig. 71.—Parallel rays of light brought to a focus in the retina of a myopic eye by means of a concave sphere placed before the eye.

lenses from its beginning have a development of the ciliary muscle equivalent to the emmetropic eye.

Some cases of myopia develop so rapidly as to be a distinctly diseased condition. This is called progressive myopia.

Etiology.—Myopia is peculiar to the human race, and is found more frequently in civilized than in uncivilized peoples. The condition may be found in several generations of the same family, but is very rarely congenital, the development coming on slowly some years after birth. In the hereditary cases it is rather the inheritance of weak coats of the eye rather than an inheritance of the myopic condition.

The *anatomic* reason for development of myopia is found in the large orbit and wide face, which necessitates excessive

convergence, and this excessive effort brings about an elongation of the eyeball.

The *mechanical* is similar to the anatomic cause in that when eyes are placed far apart, the internal recti muscles press upon the globes in the act of convergence, and in this way flatten the eye laterally. This results in the bulging of the eye in its area of least resistance, which is the posterior pole. There is found in many cases of myopia a definite globular bulging in the area between the disc and macula, which is called a posterior staphyloma.

The *inflammatory* cause is found in a low-grade inflammation which attacks the posterior pole of the eye, and this is manifested by ophthalmoscopic examination in a condition known as choroiditis, a moderately frequent accompaniment of myopia. This inflammation is brought about by a faulty use of the eyes, both in school and at home. The light may be bad, which requires the child to assume a stooped attitude. This bending down over the book or work interferes with the proper circulation of the blood in the retina and choroid.

Uncorrected errors of refraction, principally astigmatism, are often the exciting cause of a myopia. These errors force the child to assume strained attitudes, with the consequent development of the elongated eye.

Conic or bulging corneæ give rise to a myopic condition lying wholly in the anterior part of the eye. In these conditions the strained effort to see clearly may bring about an elongation of the posterior part of the eye, but this is rare.

Swelling of the lens, which often precedes cataract, gives rise to a pseudomyopia, also the class of cases previously described under ciliary spasm.

The chief factors in the production of myopia are hereditary tendency, the constant use of eyes for close work, especially in childhood, when the eyes are developing; sometimes impaired nutrition locally; faulty hygienic and light conditions; and, alone or combined with other factors, widely separated orbits.

Symptoms. The principal symptom is the inability to see

well in the distance. This, in the higher degrees of myopia, is accompanied by holding near objects close to the eyes. The myopic patient may complain of headaches and other asthenopic symptoms, but this is rare in simple myopia. Asthenopic symptoms are more often found when the myopia is complicated by astigmatism or muscle imbalance. The clear vision of the myope is limited to that portion of the world which lies within his far-point. In the high degrees of myopia this is a limited world.

The low grades of simple myopia often cause the patient no annoyance: near vision is clear and sustained without much effort, and while the distant vision is not clear, it seems to satisfy the individual in many cases.

The myopic patient is usually studious and sedentary in his habits, for his limited vision naturally directs his tastes to things which lie within his far-point, and these are study, books, music, or, if a girl or woman, fancy-work and needlework of all kinds. It is rare that the myope rejoices in out-of-door sports, unless their myopia was corrected at an early age, and even then they are compelled, through the handicap of their glasses, to indulge in the less strenuous games. Golf is an ideal out-of-door game for the myope whose refractive error is corrected.

Distant and near objects appear larger to the myope than to the emmetrope or hypermetrope, because of the larger retinal image. This leads to some confusion when correcting lenses are first worn.

Progressive myopia differs from simple myopia in that an eye manifesting progressive myopia is almost always a diseased eye. The anteroposterior axis increases rapidly in length, and there are frequently limitations in the field of vision, due to scotomata caused by choroidal and retinal atrophy.

In this form the patient complains of eye fatigue, pain, and frequently photophobia and irritation. There may be a coincident conjunctivitis and blepharitis, and retinal hyperemia. The eyeballs are frequently sensitive to palpation, and the eyes

appear to be convergent, because of the small size of the angle alpha. Muscæ volitantes, or floating specks before the eyes, are due to the choroidal degeneration of fetal remains in the vitreous, which become more apparent when the eyes are in an irritable condition.

The internal recti may refuse to act properly, and the eyes often become divergent. In high degrees of myopia one eye only may be used for near, the image of the other eye being suppressed, as in looking through a microscope. This is unconsciously done by the patient in order to do away with the strong effort of convergence.

Diagnosis.—The eyeballs are usually prominent, and the patient squeezes the lids together in order to get a clearer image. The face is frequently broad, with a wide interpupillary distance. Most cases of divergent squint have myopia, unless the squint is of traumatic origin.

The distant vision is poor, while the near vision is good, the patient doing the finest kind of near work with ease. The retinoscope will show the retinal illumination moving *against* the mirror, and the ophthalmoscope will necessitate a concave lens behind the sight-hole before the fundus details can be made out.

By the indirect method with the ophthalmoscope, when the objective lens is withdrawn from the eye, the disc grows larger if the condition is myopia, in contrast to the diminution in size of the disc under the same conditions in hypermetropia.

By direct method with the ophthalmoscope a crescent-shaped area of choroidal atrophy is frequently seen on the temporal side of the optic disc. This area is usually called the "myopic crescent." The disc may also appear displaced toward the nasal side. This is due to the bulging of the posterior staphyloma.

If patches of choroidal atrophy are seen, they will sometimes have pigment patches within them or at their borders. This condition is often called myopic choroiditis.

Retinal detachment is not an infrequent complication of

high myopia. It is due largely to degenerative changes in the vitreous.

Refraction.—The presence of myopia will have been determined by the various methods of diagnosis at our hand, and the first test made is usually the subjective.

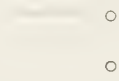
The patient is seated at the trial-case, and the trial-frames accurately adjusted. Before the eye not under examination is placed a shield. The visual acuity is first tested and recorded. This will be found decreased proportionately to the amount of the myopia. Concave spherics are then placed before the eye until best vision is obtained. The weakest minus spheres giving the best visual acuity will correct the manifest myopia. The manifest myopia may, in some instances, be greater than the total myopia, and great care must be exercised, especially by the beginner, that the weakest concave sphere giving best vision is prescribed.

Any use of the accommodation by the patient in the subjective tests or the tests by retinoscopy or the ophthalmoscope will require a stronger lens than really corrects the myopia. It is, therefore, just as necessary to use a cycloplegic in myopic children, as in those who are hypermetropic. Their accommodation is still active, and they will use it, unless the ciliary muscle is paralyzed. In older patients a cycloplegic is not so necessary as in children, except in the low grades, which, when complicated with a slight astigmatism, are among the most annoying forms of ametropia. As in hypermetropia, the necessity for the use of a cycloplegic in patients over twenty-five or thirty years of age must be left to the judgment of the physician. He can be governed by the results of the tests at the preliminary examination.

If the condition is one of simple myopia, the weakest minus sphere giving the best vision will show, with the retinoscope, a round, even light area moving with the mirror, which should neutralize with a +1.00 sph. The vision with this correcting lens should be 20/20, or better if the myopia is not of too great amount, and there are no pathologic changes in the retina and

choroid. High grades of myopia of long standing, without the use of correcting lenses, very rarely see normally, even with full correction.

By retinoscopy the light area moves *against* the mirror if the myopia is greater than 1 D. Should the light area neutralize with a +0.50 sph., the myopia will be 0.50 D., as −1.00 is added to the retinoscopic result, +0.50 S + −1.00 = −0.50. Should the retinoscope reveal a neutralized retinal illumination, the result is recorded thus:



−1.00 is added in each principal meridian and the result is as follows:

In other words, the myopia is 1.00 D. Should the myopia be of higher degree, and it takes a −9.00 sph. to neutralize the light area, the myopia would be 10.00 D. If the retinoscopic results are correct, a −10.00 sph. in the above case would give the best vision.

Myopia is a condition which is very liable to increase, and the increase is best prevented by the careful estimation of the refractive error, and the correction worn constantly. There are some cases under the presbyopic age which require a less strong lens for near work than for distance, but these cases are not so common as was formerly supposed. With encouragement and patience the myope under forty will almost always be able to wear the same pair of glasses for distance and near use. The patients with whom the greatest difficulty is found are those who have not had their myopia corrected until late in life, or those who have used their glasses only for distance. Many patients of the latter class are seen, and unless their myopia shows a

tendency to increase, they may be allowed to use their eyes for near without lenses. If, however, there is any tendency for the myopia to increase, these patients must be encouraged to wear lenses for near, even if they are less strong than the lenses prescribed for distance.

Children carefully measured under cycloplegic test should be given the weakest lens giving best vision for constant use. The weakest lens giving best vision under a cycloplegic will be found to be less strong than the weakest lens giving best vision without a cycloplegic. The lens found under cycloplegic test should be the one prescribed. That the ciliary muscle is active in children and has had little chance to atrophy is an additional reason for prescribing full correction for constant use.

The individual case is quite unlike any other, and the physician must be guided by his judgment and the requirements of the patient in prescribing myopic lenses. Where the full correction can be worn, or very slightly under full correction, for constant use the normal is more nearly approached, which is the result for which we are striving.

The trial-case test for any refractive error, but especially myopia, should never be accepted as final, and the lenses found at this test should never be prescribed unless verified by the several objective tests.

When a myopia is overcorrected by prescribing too strong lenses, the eyes are put in a condition which may be called a false hypermetropia. Accommodation must be used to obtain best distant vision, and a greater amount than normal of accommodative effort is necessary for near. Patients wearing such lenses suffer from all the symptoms of hypermetropia, and are straining a diseased eye unnecessarily.

Certain myopic eyes show many signs of inflammation, such as choroiditis, vitreous opacities, and increasing posterior staphylomata. In these cases the strength of the glasses should be but moderate at first, and, as improvement is noted, the strength should be increased to the full amount of the error as rapidly as the condition of the eye warrants.

There seems to be a queer superstition, which originated in some unknown source, but which has been handed down as Gospel by many text-books, to the effect that cases of progressive myopia should be undercorrected, and that unfortunates suffering from this severe condition must abstain from all use of the eyes for months and even years. This seems faulty teaching, and at this point the author must insert two cases which go to prove that such extreme measures are unnecessary, and may even be harmful.

Case I.—Young girl, thirteen years of age, applied for refraction in October, 1905. She gave a history of having worn glasses for three years, during which time she had been under the care of one optician and two oculists. She was wearing at the time a −5.50 sph., both eyes, which lenses were the strongest she had ever worn. She had been taken from school, which caused her great disappointment, as she was an ambitious little student. With the −5.50 spheres her distant vision was less than 1/30.

Examination three days later under atropin cycloplegia revealed 21.00 D. of myopia, combined with 2.00 D. astigmatism, axis 180 in the right eye, and 18.00 D. of myopia, combined with 2.00 D. astigmatism, axis 180 in the left eye. Correcting lenses gave vision as follows:

O. D. −21.00 sph. ⊂ −2.00 cyl. 180° = 20/70
O. S. −18.00 sph. ⊂ −2.00 cyl. 180° = 20/70

Thorough examination of the media and fundus failed to reveal any definite pathologic change other than large posterior staphylomata.

Post-mydriatic visit gave the following test:

O. D. −18.00 sph. ⊂ −2.00 cyl. 180° = 20/70
O. S. −18.00 sph. ⊂ −2.00 cyl. 180° = 20/50−

These lenses were ordered for constant use, and the patient told to report in two weeks. She reported to the effect that she

did not know the world was so beautiful. Some reading in a good light was permitted, and in a month the child was back in school.

A year later homatropin examination showed an increase of but 0.50 D. myopia in left eye and none in the right. In school the little patient had caught up with her chums and was correspondingly happy. Vision in both eyes 20/50−.

Case II.—Boy of sixteen. Had worn glasses four years, but had been myopic since five years of age. Vision had grown gradually, but steadily, worse each year. Was wearing −7.00 sph. both eyes. Atropin test showed 16.00 D. of myopia in both eyes, with 1.50 D. of astigmatism, axis 180. Ophthalmoscopic examination showed large crescents and deep posterior staphylomata, with some choroidal atrophy between disc and macula.

Postcycloplegic visit gave following test:

O. D. −16.00 sph. ⌒ −1.50 cyl. 180 = 20/50
O. S. −16.00 sph. ⌒ −1.50 cyl. 180 = 20/40−

Glasses were ordered for constant use, which were worn with comfort after about ten days.

An examination at the end of a year under homatropin cycloplegia showed no measurable increase in the myopia.

Myopia must be carefully refracted, always under a mydriatic in children, and in younger adults who manifest a low grade of the condition. Full correction must be worn constantly under the presbyopic age, if possible, except in eyes showing active inflammatory symptoms, and these can be gradually brought up to full correction or very near it. Cases showing but a low error, in which the myopia is not increasing, should be instructed to wear their glasses constantly, but if they will not do so, there will be little harm in going without them for near use. Progressive cases in children showing no signs of active inflammation should have full correction for constant use.

Aside from correcting the refractive error it is essential to instruct the patient in regard to the use of the eyes.

A good clear light is essential, and it should preferably fall over the left shoulder. If artificial light is used, this should be properly shaded. Experience has proved that a yellow shade is superior to other colors.

Myopes should not be allowed to use their eyes too long for near work. After the myopia is corrected, these patients will be more inclined to take up less sedentary habits, and in this they should be encouraged.

The old habit of bending over the work should be corrected and a more natural attitude assumed when engaged in reading, writing, or other near work.

The general health of these patients is liable to be below normal, and the duty of correcting this is often given to the family physician, who should see that suitable tonics are prescribed and an out-of-door life encouraged.

In cases of progressive myopia or other forms showing diseased conditions it may be necessary to insist upon absolute rest of the eyes for many months. The myopic correction should be partly or wholly corrected, but the eyes must be rested by the use of smoked lenses, and not infrequently a cycloplegic. Internal medication is of value. Syrup of the iodid of iron is very valuable in children, and in older people potassium iodid, iron, or strychnin may be of value.

Parents who have myopia should watch their children closely and should take a child to a competent ophthalmologist upon the appearance of the earliest symptoms of myopia.

The divergent strabismus frequently accompanying myopia is described in a subsequent chapter.

Myopia of high degree is often treated by extraction of the lens. Further information on this question can be found in any standard text-book on diseases of the eye.

CHAPTER X

ASTIGMATISM

Astigmatism may be defined as that condition of the eye in which the refraction of the two principal meridians is different; or the condition of the eye in which the two principal meridians have a different focus (Fig. 72).

The irregularity is found largely in the cornea, but it must be remembered that an irregular curvature in one portion of the eye may be neutralized by an irregularity in other portions of the eye.

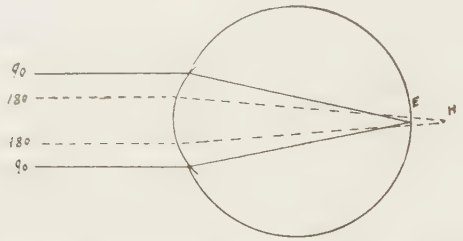


Fig. 72.—Simple hypermetropic astigmatism in which the rays of light entering in the axis 180° focus behind the retina at *H*, and those entering the axis 90° focus on the retina at *E*.

Normally, the cornea is more ellipsoid than circular, the shortest radius of curvature lying in the vertical meridian.

In regular astigmatism the meridians of maximum and minimum refraction are at right angles to each other, and in measuring the refractive error these two meridians alone are considered.

Astigmatism is the commonest of all refractive errors. Most cases of myopia and hypermetropia are complicated with astigmatism, and it is rare to find any eye without some degree of astigmatism, however slight.

Astigmatism is found mostly in the cornea, but it is also lenticular and even retinal.

Parallel rays of light passing though a convex sphere come to a focus at a point. If the cone of light thus formed is divided at right angles to its axis at any point between the lens and its

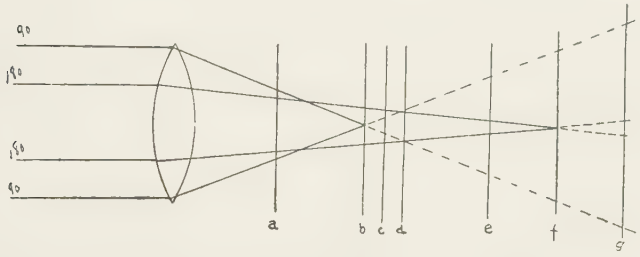


Fig. 73.—Refraction of rays in regular astigmatism.

focus, or beyond the focus after the rays have crossed and are divergent, a circle is formed.

If parallel rays of light pass through a convex glass, the vertical meridian of which is more curved than the horizontal, the rays which pass through the vertical meridian come to a

Fig. 74.—Retinal images of a point in the different forms of astigmatism (de Schweinitz): *A*, Compound hyperopic astigmatism; *B*, simple hyperopic astigmatism; *C D E*, mixed astigmatism; *F*, simple myopic astigmatism; *G*, compound myopic astigmatism.

focus in front of those which pass through the horizontal. Right-angle sections of such a cone will be more or less oval, a circle being formed at only one point (Fig. 73, d). Fig. 74 shows the shape of the diffusion patches thus produced.

At *a* an oval is formed; at *b* the horizontal straight line shows

that rays of light passing through the vertical meridian have come to a focus; at *c d e* the rays of light passing through the vertical meridian are becoming divergent; *d* shows the true circle formed by divergent and convergent rays from the vertical and horizontal meridians respectively; at *f* the vertical straight line shows the rays of light passing through the horizontal meridian which have come to a focus; and *g* shows the vertical ellipse made by the diverging rays of both vertical and horizontal meridians. The space lying between the focus of the vertical meridian and the focus of the horizontal meridian (*b* to *f*) is called the interval of Sturm. This interval represents the astigmatism.

There are two principal kinds of astigmatism, irregular and regular.

Irregular astigmatism may lie in the lens or the cornea. When in the lens, it is usually a congenital defect, or, more rarely, is acquired from changes taking place in the lens itself, or is due to displacement of the lens. Irregular astigmatism is usually corneal, and is due to conic cornea, nebulæ, or leukomata. Such cases are very hard to refract, and the vision may only be improved by the use of the pin-hole disc or stenopeic slit.

Normal irregular astigmatism is of no refractive importance. It is present in all eyes, and is due to irregularities in the refractive power of the various sectors of the lens, so that a distant luminous point appears stellate. This phenomenon is noticed every time we look at a star, which really is not stellate, but round.

Physiologic astigmatism is voluntary, and is produced by contraction of the extra-ocular muscles. In subjective tests the patient should never be allowed to squeeze the lids together, as the astigmatism produced in this way may be of great enough amount to change the measurement of the refractive error.

Regular astigmatism if that form of refractive error defined in the first paragraph of this chapter. It is divided into five

principal varieties: (1) Simple hypermetropic astigmatism. (2) Compound hypermetropic astigmatism. (3) Simple myopic astigmatism. (4) Compound myopic astigmatism. (5) Mixed astigmatism.

In astigmatism the vertical is usually the meridian of the shorter radius of curvature, and the horizontal the meridian of the longer radius of curvature. In other words, the vertical meridian has the greater refractive power. When this is so, the astigmatism is said to be *with the rule.*

If the vertical is the meridian of the longer radius of curvature, and the horizontal the meridian of the shorter radius of curvature, the astigmatism is said to be *against the rule.* Astigmatism with the rule is the form usually found.

Simple Hypermetropic Astigmatism. In this form of astigmatism one meridian is emmetropic, the other hypermetropic. The emmetropic meridian is usually the vertical, or what may be called the "vertical area," which is more fully described later in the chapter. The horizontal meridian is usually hypermetropic. The vertical meridian focuses parallel rays of light on the retina, the horizontal meridian focuses back of the retina (Fig. 72). The correcting lens is a convex cylinder placed before an eye with its axis in the axis of the emmetropia. This axis will be in what is termed the vertical area. Example: +1.25 cyl. axis 100. The retinal image, instead of a point, as in emmetropia, is a horizontal line (b, Fig. 74). The correcting cylinder produces a point image similar to emmetropia.

Compound Hypermetropic Astigmatism. —This condition is found in nearly 45 per cent. of all cases of refractive error, and is most common of all forms of refraction. In this form of astigmatism with the rule, both meridians are hypermetropic, but the horizontal meridian is more hypermetropic than the vertical. Parallel rays of light passing though the vertical meridian focus behind the retina, measuring the amount of hypermetropia. Parallel rays of light passing through the horizontal meridian focus at a point behind the focus for the

vertical rays (Fig. 75). The difference between these two points is equivalent to the astigmatism. The retinal image is an oval (c, Fig. 74).

The correcting lens is compound, an example of which is written— +2.00 sph. ⌓ +0.75 cyl. 85°.

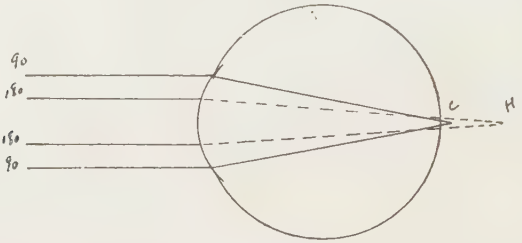


Fig. 75.—Compound hypermetropic astigmatism.

Simple Myopic Astigmatism.—This condition is comparatively rare. Parallel rays of light passing through the vertical meridian come to a focus in front of the retina, while those passing through the horizontal meridian come to a focus on the retina (Fig. 76). In simple myopic astigmatism with the rule the area of the horizontal meridian is emmetropic, the meridian at right angles to horizontal meridian is myopic.

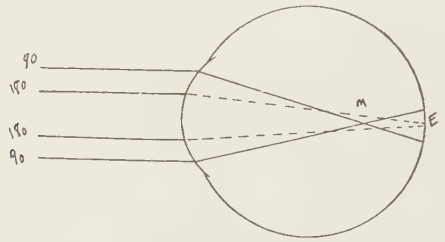


Fig. 76.—Simple myopic astigmatism.

The retinal image is a line placed more or less vertically (f, Fig. 74).

The correcting lens is a concave cylinder placed before the eye in the axis corresponding to the emmetropic axis. An example: −2.00 cyl. 170°.

Compound Myopic Astigmatism.—Most all myopic eyes have some myopic astigmatism. Simple myopia is not often seen. Parallel rays of light passing through both meridians of such an eye to a focus in front of the retina, but the rays passing the vertical meridian focus in front of those passing through

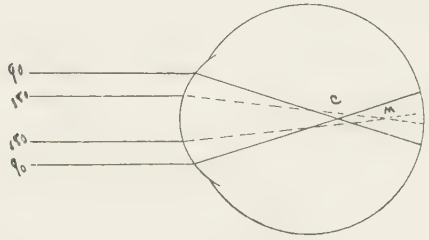


Fig 77.—Compound myopic astigmatism.

the horizontal meridian (Fig. 77). The retinal image is a vertical oval (g, Fig. 74).

The correcting lens is compound, and is written as in the following example: − 3.00 sph. ⊂ − 2.00 cyl. 180°.

Mixed Astigmatism.—An eye manifesting this condition is hypermetropic in one meridian and myopic in the other.

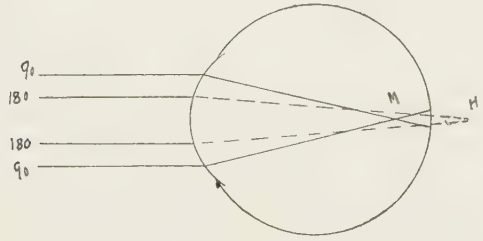


Fig. 78.—Mixed astigmatism.

Parallel rays of light passing through the vertical meridian come to a focus in front of the retina, and the rays passing through the horizontal meridian come to a focus behind the retina (Fig. 78).

The retinal image is a circle or an oval (d e, Fig. 74).

The correcting lens of a mixed astigmatic eye is compound, and may be written in three ways:

(1) +2.00 cyl. 90° ⌒ −2.00 cyl. 180°.
(2) +2.00 sph. ⌒ −4.00 cyl. 180°.
(3) −2.00 sph. ⌒ +4.00 cyl. 90°.

The Meridians of the Eye.—The various axes or meridians of the eye are indicated by 5-degree markings on the periphery of the trial-frame (Fig. 53), which correspond to imaginary lines drawn from the apex of the cornea to the posterior pole. These axes range from 0 to 180, both horizontal. The vertical axis is 90. Both eyes are marked alike, starting from 0 on the left-hand side of the horizontal meridian, and passing to the right through an arc of 180 to the right-hand horizontal line.

Symmetric astigmatism is when the combined value in degrees of the meridians of the shortest or longest radii of curvature in both eyes equals 180. For example, if the cylinder correcting the astigmatism of the right eye is placed in axis 80 and the cylinder of the left eye is placed in axis 100, these added together equal 180. The same is true if each cylinder is placed at 90. If both cylinders are placed in axis 180, the astigmatism is also symmetric, one being called 0.

Asymmetric astigmatism is when the combined value in degrees of the cylinder axes of both eyes does not make 180. The combined value may be more or less. If, for example, the cylinder correcting the right eye is placed in axis 105, and the cylinder of the left eye is 120, the combined value is 225. Or, again, the cylinder correcting the right eye may be placed in axis 45, and that correcting the left eye in axis 75. The combined value will be less than 180, or 120.

A convex cylinder which is placed in any necessary axis within 45 degrees of 90 is said to correct an astigmatism with the rule; a concave cylinder placed in any axis within 45 degrees of 180 is said to correct an astigmatism with the rule. In other words, the cylinder correcting hypermetropic astigmatism with the rule is placed more or less vertically; the cylinder correcting

myopic astigmatism with the rule is placed more or less horizontally.

Etiology.—Congenital malformation of the refracting surfaces or media of the eye is the most common form. The amount of this irregularity varies somewhat with time, and such eyes need reëxamination every three or five years, or as symptoms suggest possible change.

Acquired astigmatism is due to operations on the cornea or sclera, such as cataract extraction, iridectomy, etc., and to cicatricial contraction from wounds, ulcers, and other inflammatory changes in the anterior portion of the eye. This form also varies with time, and in some cases disappears completely. This is especially true some months after cataract extraction or iridectomy.

Symptoms.—The symptoms are those of asthenopia generally, although there are no symptoms of astigmatism which may be called typical of this refractive condition. An exception to this is in the very high degrees in which one axis may be normal or nearly so, and the other highly astigmatic.

One case under my observation could not see the hands of the clock when they pointed to six or twelve o'clock until he had turned his head at nearly right angles to his body. In the upright position quarter to three was plainly seen. In this case a strong convex cylinder, axis 180, enabled the patient to see very well indeed.

Standish, in a lecture given some years ago, suggested the interesting theory that the first impressionists were uncorrected astigmatics. A long pole held before the work of the earlier impressionists in a certain consistent axis showed the details of this axis to be clear, while the axis at right angles was blurred. Standish held that these men had created a new school of art only because they really saw things as they painted them. By means of the stereopticon he threw ordinary pictures on the screen magnified by a convex spheric lens, and they gave perfect detail in all meridians. The same picture was later thrown on

the screen through a convex cylinder, and the result was an impressionistic picture.

Diagnosis.—This is made by numerous subjective and objective tests, which will be described in the order of their importance:

1. Astigmatic chart.
2. Retinoscope.
3. Ophthalmoscope.
4. Stenopeic slit.
5. Cylindric lenses.
6. Pointed line test.
7. Placedo's disc.
8. Pray's letters.
9. Ophthalmometer.

1. *The Astigmatic Chart Test.*—The various kinds of these charts are without number, each author or designer advocating

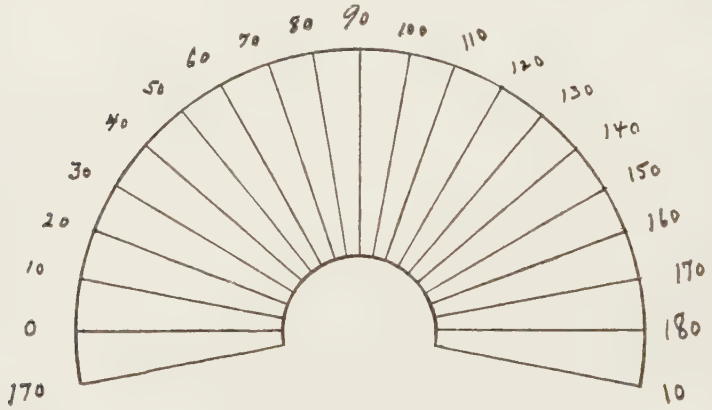


Fig. 79.—Astigmatic chart No. 1.

special merits for his own. There is no occasion for more than two. The first (Fig. 79), consisting simply of radiating lines placed at 10-degree intervals, and the second (Fig. 80), the chart No. 2 of the author. This second chart is used for the finer tests of astigmatism after the axis has been determined by the radiating line chart. The "clock dial" (Fig. 81),

strongly recommended by some authors, is not suited for the finer determinations of the 5- and 10-degree deviations of the

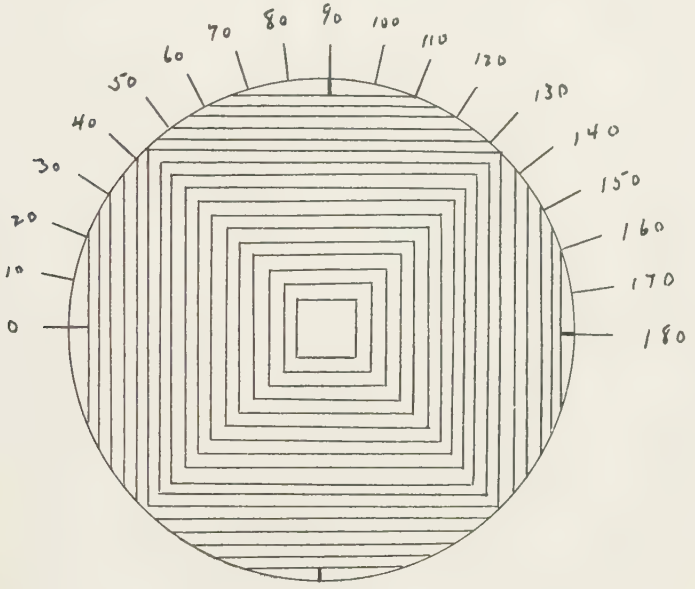


Fig. 80.—Astigmatic chart No. 2.

astigmatic axis. The radiating lines are separated by 30-degree intervals, which is by far too much. The single line 10-degree interval chart determines the axis accurately. Should,

Fig. 81.—Clock dial.

for example, the line marked 100 be pronounced by the patient the clearest line when the patient's vision is "blurred," the cylinder correcting such an error will be placed in the trial-

frame in the axis 100, if hypermetropic astigmatism is present, and at axis 10, if myopic astigmatism. Should the lines 70 and 80 be seen with equal clearness and all other lines appear dull, the axis of the correcting cylinder will be 75 if convex and 105 if concave.

When testing for the axis with the radiating line chart, the eye should always be in a condition of myopia. If the patient is myopic, no lens need be in front of the eye under examination, or if, on account of a high degree of myopia, some must be corrected in order to see the lines, the myopia should be *undercorrected* from 1.5 D. to 3.00 D. If the patient is hypermetropic, the patient should be *overcorrected* from 1.5 D. to 3.00 D.

Patients whose eyes are blurred choose the lines of the vertical area when their astigmatism is with the rule. If the lines in the horizontal area are clear, the astigmatism is against the rule.

The use of the second chart will be fully explained under Refraction of Astigmatism.

2. *Retinoscopy.*—The principles of retinoscopy have been described. The diagnosis of astigmatism is made by the band of light seen by the retinoscope, which moves more slowly at right angles to its axis than in its axis.

3. *The Ophthalmoscope—Direct Method.*—Astigmatism is diagnosed by this method from the fact that the blood-vessels in the principal meridians are not seen with equal clearness with the same lens behind the sight-hole of the ophthalmoscope. This is equally true of the details of the fundus. The character of the astigmatism is determined by the lenses necessary to see the details of each meridian plainly, and the amount is equal to the difference in the refractive lenses. If a +2.00 sph. is necessary to see the vessels in the vertical meridian clearly, this represents the amount of the hypermetropia in the horizontal meridian. In other words, the lens necessary to see the vessels in one meridian clearly measures the refraction of the meridian at right angles to it.

The disc may appear oval, and the sides of the disc, the upper and lower, and the two lateral sides, are seen by lenses of different strength.

By the *indirect method* there is little seen of diagnostic value other than the elongation of the optic disc.

4. *The Stenopeic Slit* (Fig. 41).—This is a round disc the size of the trial-lens, and has in its center a slit-like opening about 25 mm. long and usually 1 or 2 mm. wide. The narrower opening is to be preferred. When this slit is placed before the eye in the vertical meridian, all rays of light in the horizontal meridian are excluded; when placed in the horizontal meridian, the vertical rays are excluded. For determining the astigmatic axis the slit is placed in the trial-frame before the eye to be examined, the other being covered, and it is slowly revolved while the patient looks at the letters on the test-card. If the vision remains unchanged, regardless of the axis of the slit, astigmatism *may* be absent, but if the patient sees the letters most clearly with the slit in one axis and sees them least clearly with the slit at right angles to this, astigmatism is usually present. The astigmatism is in the axis of poorest vision, and the correcting lens should be placed in the axis of best vision. The amount of the astigmatism is determined by the difference in the strength of the sphere necessary to bring the vision in each axis up to normal. For example, should a +1.00 sph. be necessary to give normal vision in axis 10; and a +2.50 sph. necessary to give normal vision in axis 100, the astigmatism would be 1.50 D., and the correcting lens would be +1.00 sph. ⊂ +1.50 cyl. 10°. This test is of most service in irregular astigmatism, conic cornea, and aphakia.

5. *Cylinder Lenses.*—This will be more fully described under Refraction of Astigmatism. It consists in subjective and objective tests with the cylinder correcting the astigmatism before the eye. In the subjective test the vision should be normal when the cylinder correcting the astigmatism is placed before the eye in its correct axis. The cylinder alone will be sufficient to give normal vision in cases of simple astigmatism, or if the

patient has a compound astigmatism, the sphere will have to be added to the cylinder before the vision will be brought to normal.

The objective test is by retinoscopy. With the proper correcting lens before the eye the light area should be round and even, moving with the mirror, and neutralized with a +1.00 sph.

6. *The pointed line test* was devised by Thorington, and consists in a series of one-minute black squares in three parallel lines at right angles to each other (Fig. 82). The dial is

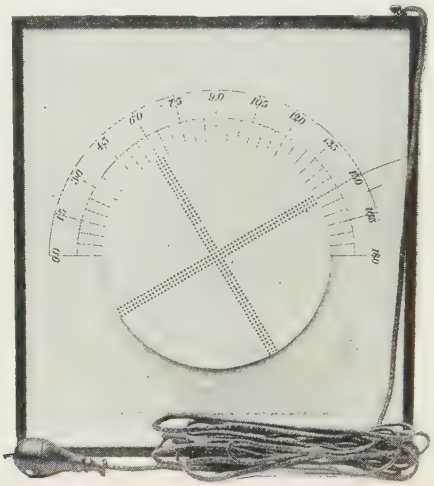


Fig. 82.—Thorington's astigmatic chart.

rotated by means of a clock work and a battery which is controlled by a button placed near the operator. The dial is rotated into the various axes until the patient signifies which series of dots resembles a line.

7. *Placido's disc* (Fig. 83) is of great value in determining the axis of corneal astigmatism in cases of conic cornea, and irregular astigmatism, and also in astigmatism following cataract operation and iridectomy. The disc is about eight inches in diameter, with a small sight-hole at its center. One side of the disc is black and the other is painted in alternate white and

black circles. These circles are not of equal width, but are arranged so that, when reflected on the cornea, they appear of equal width. On the black side behind the sight-hole is placed a slot for the insertion of a convex lens for magnifying purposes. When using this disc the patient is placed with his back to a window, the examiner holds the disc before his own eye, with the circle side toward the patient. The patient is instructed to look at the sight-hole. The eye to be examined is then approached until the corneal image of the instrument completely covers the patient's cornea. A +4.00 sph. should be placed behind the sight-hole. If corneal astigmatism is present, the circles will appear distorted or elongated, and if elongated, the examiner

Fig. 83.—Placido's disk or keratoscope.

Fig. 84.—Pray's letters.

can determine the axis of the astigmatism, which is frequently hard to determine by the usual methods in cases of irregular astigmatism. The stenopeic slit is superior to the disc as a diagnostic test, but the latter may be used in cases of doubt.

8. *Pray's letters* (Fig. 84) are of Old English type, and are

made up of black lines which run in different meridians. The test consists in the patient selecting the letter which appears to him the blackest. For this test the vision should be preferably "blurred," as in the astigmatic chart test. The letter chosen will be in the axis of least ametropia.

9. *The Ophthalmometer* (Fig. 48).—This instrument, which has been described in Chapter II., measures as nearly accurately as any at our command the *corneal* astigmatism. Unfortunately, astigmatism, while usually corneal, is not wholly so, for an irregularity in the curvature of the cornea may be neutralized by an irregularity in the lens, and even in the retina. For this reason the use of the ophthalmometer in the routine estimation of refractive errors is to be condemned as unreliable, the results obtained when the crystalline lens is in the eye being more often incorrect than correct, and the amount of astigmatism, as shown by the mires, and even the axis, are, to say the least, misleading.

In cases of pure corneal astigmatism, such as is found after cataract extraction, and in eyes known to have been of normal refraction before operation for iridectomy, the ophthalmometer is of value, but it is of value in these cases only.

In cases of conic cornea the amount of the astigmatism can rarely be measured with the ophthalmometer, but it is of value in the diagnosis of this condition. The images of the mires cannot be made to come in contact in marked cases of this disease, but they are seen on the patient's cornea much distorted, and they frequently are seen to pulsate synchronously with the beat of the heart.

In the routine estimation of the refractive error the ophthalmometer has become practically obsolete, except for the mental effect upon the patient, which may in some cases be useful, but is rarely necessary.

When making the test, the patient is placed before the instrument in as comfortable a position as possible, so that the images of the illuminated mires will appear upon his cornea. The observer looks through the telescope and focuses the center

of the patient's cornea until the images of both mires are clearly seen. The two center images are selected and, by means of the mechanism which moves the mires, the two are approached until the images are in contact in the center of the cornea, and the black line in each makes one continuous black line in both (Fig. 85). In order to accomplish the latter it is usually necessary to rotate the barrel of the telescope either to the left or the right, but never more than 45 degrees. When this posi-

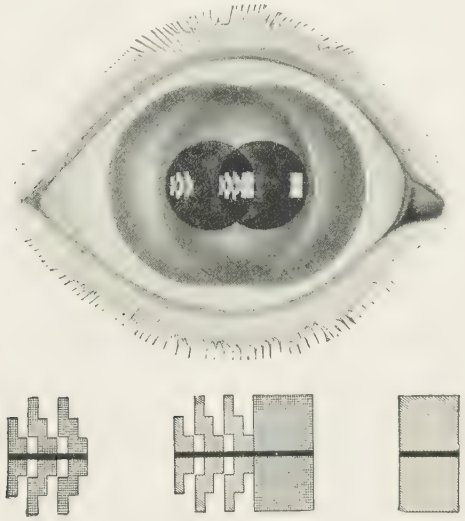


Fig. 85.—Primary position of the ophthalmometer, showing the mires in approximation.

tion is obtained, the axis or meridian is noted and recorded. This is called the primary position.

The telescope is then revolved to the opposite axis, at right angles to the primary position, which is called the secondary position. If, in the secondary position, the edges of the mires remain in apposition, there is no corneal astigmatism, but should the mires have encroached upon one another, astigmatism is calculated by the amount of the overlapping of the steps (Fig. 86). Each step represents 1.00 D. of astigmatism.

Should the mires separate in the secondary position, the

mires at first having been in the horizontal meridian, the astigmatism is against the rule, and the mires must be opposed in the vertical meridian first. In this case the secondary position will be the horizontal meridian.

Refraction.—Having arrived at the diagnosis of astigmatism by the various methods at our command, the estimation of the amount and axis are next to be determined. As the method of procedure varies somewhat for each variety of astigmatism, they will be separately described.

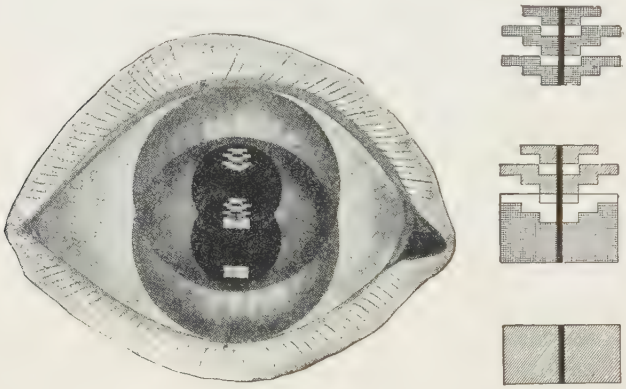


Fig. 86.—Secondary position of the ophthalmometer, showing overlapping of the image of the mires.

Simple Hypermetropic Astigmatism.—The patient is seated at the trial-case, facing the test-card placed about 6 meters away. The trial-frames are accurately adjusted and centered. The right eye is usually examined first, the other being covered. The visual acuity is first taken and recorded. Plus spheres of increasing strength are then added until the smallest line of letters seen becomes blurred. In simple hypermetropic astigmatism a weak sphere will blur the smallest letters seen without a glass. Should, for example, a +50 sph. blur the 20/30 line, which line was the best vision of the patient with or without the spheric lens, a +2.00 or +2.50 sph. is placed before the

eye, which will completely "fog" the test-letters. Astigmatic chart No. 1 (Fig. 79) is then placed before the patient, and he is asked to select the clearest lines on the chart. If the line chosen as the darkest is 90, this is the axis in which the correcting cylinder is placed; if the lines 90 and 100 are seen with equal distinctness, all others being more blurred, the axis of the correcting lens will be 95. It sometimes happens that three lines are seen more plainly than the rest—for example, 100, 110, 120; the axis will then be the center line, or 110. When the axis is determined by Chart No. 1, Chart No. 2 (Fig. 80) is then placed before the patient with one set of fine lines placed in the chosen axis. Should this axis have been 100, the dial of Chart No. 2 is rotated so that one set of fine lines is in the axis 100 and the other set in axis 10. If the fine lines are not made out, the vision is too much "fogged" by the plus sphere, and the strength of this will have to be reduced. It must be kept in mind, however, that all the fine lines must be blurred, but one set will be more blurred than the other. The fine lines running parallel to the axis chosen on Chart No. 1 will be more plainly seen than those at right angles to them. Concave cylinders of increasing strength are now placed over the plus sphere, in the axis at right angles to the axis chosen on Chart No. 1, until the fine lines in the whole card are seen with equal distinctness. The strength of the cylinder necessary to produce this equality measures the amount of the astigmatism. A convex cylinder of equal strength to the concave cylinder is then placed in the trial-frame in the axis chosen on Chart No. 1, and the convex sphere, or fogging glass, removed. This convex cylinder should give normal visual acuity.

The fogging method above given is resorted to whether or not a cycloplegic is used. This method does away with the necessity of using a cycloplegic in many cases over twenty-five or thirty years of age.

After the second eye has been tested in a similar manner the patient is placed in the dark-room, with his correcting lenses

in the trial-frame. *Retinoscopy* will then show a round, even shadow, moving with equal rapidity in all directions with the mirror. This shadow will be completely neutralized in all meridians with a +1.00 sph. if the astigmatic chart test has been correct. Retinoscopic results are, of course, more accurate when the eye is under the influence of a cycloplegic.

The ophthalmometer may be used to verify the astigmatic axis determined by the chart test.

In children and illiterates who are unable to read the test-types a cycloplegic test should always be made, and if a cycloplegic is used in other patients, as will most often be the case, the retinoscopic results will be obtained first. The light area will be seen to move more rapidly in the vertical meridian than in the horizontal, if the astigmatism is with the rule. A defined band of light will be seen in many cases (Fig. 57).

The vertical meridian will neutralize with a +1.00 sph., and the horizontal meridian with a stronger plus sphere. The results are recorded as in the following example:

O. D.	O. S.
+2.50	+2.25
+1.00	+1.00

−1.00 is added to these results, and the correcting lens will be written:

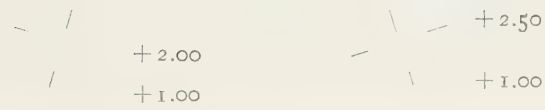
O. D. +1.50 cyl. 90°.
O. S. +1.25 cyl. 90°.

These lenses should give normal vision.

The astigmatic axis is much more frequently found "off axis" than perfectly vertical. The astigmatic chart test and the retinoscope will usually show the axis in the "vertical area," but not at 90 degrees. In 1000 consecutive cases in private practice the astigmatism was off axis in 70 per cent.

In recording the retinoscopic results the cross is tilted in the astigmatic axis thus:

O. D. O. S.



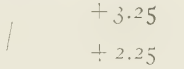
Compound Hypermetropic Astigmatism. —The subjective test at the trial-case in compound hypermetropic astigmatism is similar to that of simple hypermetropic astigmatism. Convex spheres are added to the eye examined until the smallest letters seen become blurred. A convex sphere, 1.50 or 2.00 D. stronger, is then placed in the frame, and the axis and the amount of the astigmatism determined, as previously described.

After the amount and the axis of astigmatism have been determined, a plus cylinder of proper strength is placed in the correct axis over the plus sphere, and the strength of the plus sphere is decreased by adding minus spheres of increasing strength until the vision becomes clear. The highest plus sphere combined with the proper cylinder giving best vision corrects the compound hypermetropic astigmatism. The following case will illustrate the subjective test: Visual acuity without any lens equals 20/50. +1.50 sph. gives vision of 20/30; +1.75 sph. blurs the 20/30 line. +3.00 placed before right eye as fogging glass. All lines are blurred except 20/200. Chart No. 1 shows line 80 to be the best. −1.25 cyl. 170° neutralizes fine lines in Chart No. 2. Then +1.25 cylinder, axis 80°, is placed over the +3.00 sph., and 20/20 is seen after −1.75 sph. has been placed over the plus sphere and cylinder. The correcting lens is written:

V. O. D. +1.25 sph. ⊂ +1.25 cyl. 80° = 20/20

The retinoscopic results on the above eye will be as follows:

O. D.



After adding −1.00, the results are the same as given above, namely: +1.25 sph. ⊂ +1.25 cyl. 80° = 20/20.

Simple Myopic Astigmatism.—In this form of astigmatism it is necessary to use but a weak plus sphere for fogging—+0.50 or +0.75 sph. will be sufficiently strong. Charts No. 1 and No. 2 are used as before to determine the axis and the amount of the astigmatism. After this has been determined, the concave cylinder is left in, and the weak plus sphere is removed. The concave cylinder should then give normal vision or better.

The retinoscopic findings with the correcting lenses in the trial-frame show a round shadow which should be neutralized with a +1.00 sphere.

If the retinoscope is used without the correcting lens, the horizontal axis will move with the mirror and will neutralize with a +1.00 sph. The vertical axis will move rapidly with the mirror if the myopic astigmatism is less than 1.00 D., and against the mirror if more than 1.00 D.

Example:

Adding −1.00, the correcting lens will be written −2.00 cyl. 165°.

Compound Myopic Astigmatism.—Most cases of myopic astigmatism are compound; simple myopic astigmatism is quite uncommon. In testing for this refractive error by the subjective test the diagnosis will probably have been previously determined. Concave spheres are placed in the trial-frame until the weakest sphere giving best vision has been determined. This sphere is then reduced in strength 1.50 or 2.00 D., and the astigmatism determined by the chart test, as in the varieties previously described. After the amount and axis are determined, the visual acuity is brought to normal by adding minus spheres until the lowest minus sphere combined with the proper

cylinder gives normal vision or better. In high grades of compound myopic astigmatism the best vision with correcting lenses may not give normal vision. This is especially true if the myopia has been of long standing and has been previously either uncorrected or only partially corrected. Myopia corrected in its incipiency will almost always give normal vision. This is an additional point in favor of its early recognition and *full* correction.

Retinoscopy will show a retinal illumination which moves against the mirror in all meridians if the myopia exceeds 1.00 D.

Example: Man, twenty-two years. Student.

V. O. D. = 20/200 − 3.50 sph. = 20/40
V. O. S. = 20/300 − 4.00 sph. = 20/40

Astigmatic chart test shows −1.75 cyl. 180° in right eye; −1.75 cyl. 175° in left eye.

V. O. D. = 20/200 − 3.50 sph. ⊂ − 1.75 cyl. 180° = 20/20
V. O. S. = 20/300 − 4.00 sph. ⊂ − 1.75 cyl. 175° = 20/20−

Retinoscope shows with the above correction before the eyes a round, even shadow moving with the mirror, and which is neutralized in all meridians with a +1.00 sph. Retinoscopy, cycloplegic test, equals—

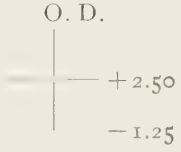
After −1.00 has been added to the retinoscopic results, the correcting lens is the same as that given above.

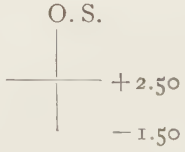
Retinoscopic or astigmatic chart results should not be taken as absolute unless the glass obtained by these results give the best vision. At best they serve as excellent guides, which enable the examiner to arrive easily at the proper cor-

rection. Several of the best tests should be used to substantiate the two tests upon which great stress has been laid in this chapter.

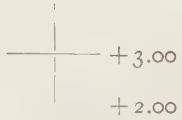
Mixed Astigmatism.—In determining the axis of astigmatism in this variety of refractive error, the vision is "fogged," as described under compound hypermetropic astigmatism, Chart No. 1 being used for this purpose. The amount of astigmatism is determined with Chart No. 2, as previously described. The mixed astigmatic eye is, let me repeat, one in which the horizontal meridian is hypermetropic and the vertical meridian myopic, or vice versâ. The best visual acuity is, therefore, obtained only when a plus and a minus lens are placed in combination before the eye. This is accomplished by three possible combinations: (1) A convex sphere with a concave cylinder; (2) a concave sphere with a convex cylinder; or (3) a convex cylinder in one axis and a concave cylinder in the opposite axis (crossed cylinder).

Retinoscopy shows a retinal illumination which moves with the mirror in one meridian and against the mirror in the meridian at right angles to the first. For instance:





In determining the amount of astigmatism from retinoscopic results it must be remembered that if the signs are alike (*i. e.*, + or −) the astigmatism is equal to the difference between the lens correcting the vertical meridian and the lens correcting the horizontal meridian. For example:



In this case the astigmatism is + 3.00 − + 2.00 = + 1.00. The correcting lens of such an eye would be written + 1.00 sph. ⌓ + 1 cyl. 90°.

If, on the contrary, the signs (*i. e.*, + and −) are unalike, the amount of the astigmatism is equivalent to the total strength of the lenses necessary to neutralize the two principal meridians. For example:

In this case the astigmatism is + 2.50 + − 1.50 = 4.00. Adding − 1.00 to the retinoscopic finding does not alter the result. The correcting lens of such an error may be written in three ways, as follows:

(1) + 1.50 sph. ⌓ − 4.00 cyl. 180°
(2) − 2.50 sph. ⌓ + 4.00 cyl. 90°
(3) + 1.50 cyl. 90° ⌓ − 2.50 cyl. 180°.

Personally, the writer favors example (2) whenever it is possible to prescribe this combination with the best results for the patient.

Irregular Astigmatism.—The results in this form of astigmatism are not very satisfactory. All methods of determining the amount and axis of astigmatism should be used. The stenopeic slit test is usually the best method of determining the proper correcting lens.

CHAPTER XI

PRESBYOPIA, APHAKIA, AND ANISOMETROPIA

Presbyopia.—As age advances many changes take place in the eye: the visual acuity becomes somewhat less, and the accommodation gradually diminishes from an early age until, at about forty-five, the near-point has receded to 22 cm. in the emmetropic eye. The age at which presbyopia occurs is not definite—this depends largely on the character of the refractive error and the physical condition of the patient.

Presbyopia may be defined as the receding of the near-point, due to the loss of elasticity in the lens substance and partially to a weakened power of the ciliary muscle, due to age. Under these conditions the near-point (punctum proximum) has receded to a point 22 cm. or more beyond the eye, and near vision is impossible without the aid of convex lenses.

If the patient manifesting presbyopic symptoms wears glasses for distance, it will be necessary to use two sets of lenses—one for distance and one for near use.

In order to see plainly at 22 cm. a positive refractive power of 4.50 D. is necessary, which is the amount of accommodative power for the emmetrope at forty years. If the near-point is beyond 22 cm., a convex sphere must be used, which will bring the refractive power up to 4.50. At sixty years of age the accommodative power is only 1.00 D., and the near-point is 100 cm. It becomes necessary to add +3.50 sph. to the correction for distance in order to bring the accommodative power up to 4.50 D.

When the near-point has receded to 22 cm., the point of easy reading distance is considerably farther away, as, in sustained near vision, only about half the accommodative

power can be used. This point must be remembered in correcting the presbyopia.

NEAR-POINTS

Age.	Near-point.	Power of Accommodation.
40 years	22 cm.	4.50 D.
45 "	28 cm.	3.50 D.
50 "	40 cm.	2.50 D.
55 "	55 cm.	1.75 D.
60 "	100 cm.	1.00 D.
65 "	135 cm.	.75 D.
70 "	400 cm.	.25 D.
75 "	infinity.	.00 D.

Etiology.—It is a well-established fact that the sclerosis of the center of the lens (the nucleus) begins at about the age of ten, and gradually continues until the lens is completely sclerosed at from sixty-five to eighty years.

Debilitating disease will hasten the advent of presbyopia. This is especially true of typhoid, malaria, Bright's disease, diabetes, influenza, etc.

Symptoms.—The chief symptom is recession of the near-point. The patient states that the distant vision is clear, but reading or any near work for the eyes is maintained with difficulty. This symptom is usually first noticed in the evening, with the use of artificial light. If the presbyopia is uncorrected or undercorrected, the patient holds his book or paper at arm's length. One patient aptly expressed his condition by saying: "My sight is all right, but my arms are not long enough."

Refraction.—Before attempting to correct the presbyopia the ametropia for distance should be fully and accurately determined. This is accomplished, according to the refractive error, by the methods given in the preceding chapters. The ametropia of the presbyope is usually determined without the aid of a mydriatic, but a mydriatic should be unhesitatingly used if the tests are at all unsatisfactory. A 1 per cent. solution of homatropin instilled into the eye two or three times at intervals of ten or fifteen minutes will usually give excellent cycloplegic and mydriatic effects in presbyopes. It is a safe rule, in patients

over forty-five or fifty years of age, for the physician to instil the mydriatic himself, or at least have the drops instilled while the patient awaits his turn, in order that he may be under the direct observation of the physician.

If a cycloplegic has been used, it will be necessary to postpone the correction of the presbyopia until the cycloplegic effect has disappeared.

It is as necessary properly to measure the ametropia of the presbyopic patient, as that of the younger patient, even though the former insists that he will wear his correcting lenses for near use only. If the patient's eyes are put in a condition of emmetropia by means of proper lenses for distance, it becomes a simple task to correct the presbyopia.

An easy distance for reading, writing, or sewing is about 13 or 14 inches. This distance is usually agreeable for most presbyopic cases, and it is at this distance from the eyes that the physician instructs the patient to hold the near test-type (Fig. 31). The age of the patient is next considered, and Thorington's rule serves as an excellent guide in applying the proper convex spheres. He adds to the distance correction +1.00 sph. at forty-five years of age; +2.00 sph. at fifty years; +2.50 sph. at fifty-five years; and a +3.00 sph. for sixty or more years.

Each eye, of course, is to be tested separately. Thorington's rule will, at best, serve as a guide, but it is an excellent guide for the average presbyopic patient. However, the occupation of the patient is of equal importance to the age. It can readily be seen that the near glass for a carpenter of fifty would hardly be suitable for a watchmaker of the same age manifesting the same refractive error. The former would need a near glass less strong than the average, and the latter a stronger near glass than the average.

The amount of presbyopia is usually the same in both eyes, but it is not so always. The lens giving the best acuity for the distance needed, and *the greatest range of accommodation*, should be the lens prescribed. After the presbyopia of *each*

eye has been determined separately, the binocular vision will give a better acuity and a greater range of accommodation than either eye alone. The range of accommodation will diminish rapidly after fifty years of age.

The fact that a patient says he has never used glasses for distance and does not need them should not warrant the supposition, on the part of the examiner, that the patient is emmetropic. The examiner should always determine the distance vision and refraction of every case. It is necessary also to examine thoroughly the media and fundi of all patients applying for presbyopic correction, it being understood that this rule applies equally to all patients under the presbyopic age.

As the power of convergence diminishes with the power of accommodation, it frequently becomes necessary to do more than merely correct the presbyopic error. This may be illustrated in the case of an engraver who is required to work steadily at a 7- or 8-inch distance. His presbyopic correction will make up for his lack of accommodation, but it will not help his convergence. In many selected cases, therefore, it becomes necessary to add prisms, base in, to the presbyopic correction. If too much convergence effort is not required, the prismatic effect may be gained equally well by decentering the lenses inward, or narrowing the interpupillary distance of the frames. The converging power can be roughly determined by having the patient look at a pencil-tip held for some time inside his near-point.

Examples:

(1) Man, forty-seven years of age; occupation, lawyer.

V. O. D. = 20/20 + 0.50 sph. = 20/20
V. O. S. = 20/20 + 0.50 sph. = 20/20

O. D. + 1.50 sph. added to the distance correction gave greatest acuity at 14 inches, and greatest range of accommodation. O. S., same.

No symptoms for distance, no complaint of eyes other than when reading or writing.

Ordered +2.00 sph. both eyes, for near use only.

(2) Woman, fifty years; seamstress. Has been myopic for thirty-five years, and has worn glasses for over twenty years. Wearing: 3.50 sph. O. D. and 4.00 sph. O. S.

V. O. D. = 20/200 − 4.00 sph. ⊂ − 0.50 cyl. 180° = 20/20
V. O. S. = 20/200 − 4.50 sph. ⊂ − 0.75 cyl. 180° = 20/20

By adding +2.25 sph. to each correction, as given above, gives greatest range of accommodation and best acuity for sewing distance.

Ordered: O. D. − 4.00 sph. ⊂ − 0.50 cyl. 180°
O. S. − 4.50 sph. ⊂ − 0.75 cyl. 180° } *distance*

Bifocal: O. D. − 1.75 sph. ⊂ − 0.50 cyl. 180°
O. S. − 2.25 sph. ⊂ − 0.75 cyl. 180° } *near*

(3) Man, fifty-five; carpenter. Has never worn glasses except for work and reading, but had noticed, within past five years, that distance vision is much worse than formerly.

V. O. D. = 20/40 + 2.50 sph. = 20/20
V. O. S. = 20/50 + 2.50 sph. = 20/20

+2.00 sph. added to O. D. and +2.25 sph. added to O. S. gives best vision at about 15 inches, which is the distance chosen by patient. Ordered above distance correction for constant use and +2.00 sph. O. D. and +2.25 sph. O. S. in hook frames to place over distance glasses when needed.

Aphakia is that condition of the eye in which the lens is absent. The condition is seen after cataract extraction or extraction of the lens for any cause. The aphakic eye is absolutely devoid of accommodation, and no matter at what age, needs two sets of lenses—one for distance and one for near use. Aphakia occurs with great rarity as a congenital condition.

Diagnosis.—Much may be told from the history of the

patient, and inspection makes the diagnosis certain. If due to cataract extraction or discission, the corneal or corneoscleral scars will reveal the site of the operation. The anterior chamber is deeper than normal, and the iris may be, and often is, tremulous. If an iridectomy has been performed, this will be plainly evident. The posterior capsule of the lens, in whole or in part, will be easily seen with the ophthalmoscope, unless the extraction had been made in capsule.

A bright flame held some little distance before the normal eye will form three images—the first, bright and erect on the anterior surface of the cornea; the second, erect and smaller on the anterior surface of the lens; and the third, inverted, on

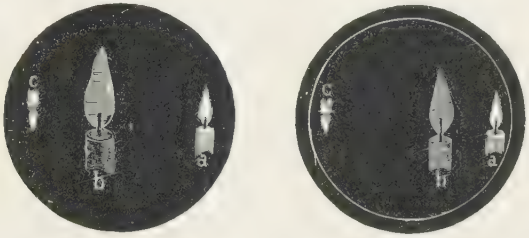


Fig. 87.—Reflected images of a candle-flame as seen in the pupil of an eye at rest and accommodated for near objects (Williams).

the posterior surface of the lens (Fig. 87). When the flame is moved, these images also move—the two upright images with the flame, and the inverted image against the flame. In aphakia the two images on the lens are absent.

Refraction.—A +10 sph. is required to make up for the loss of the lens for distance vision in the average case, the refractive condition of which was emmetropic previous to the extraction of the lens. The lens required will depend upon the previous refractive error of the patient. A myopic patient of 12.00 to 16.00 D. may not need a glass for distance after the lens has been removed. A patient formerly hypermetropic will need a much stronger convex sphere than the previously emmetropic patient.

Cases of cataract extraction usually manifest a hypermetropic astigmatism in the axis of the scar, and this astigmatism and its axis are accurately determined with the ophthalmometer or by means of the stenopeic slit. The ophthalmometer is in these cases used as a keratometer simply, and is of great value. The astigmatism is almost invariably against the rule, as the cataract incision is in most all cases made above. Astigmatism is less often found in cases where discission has been performed for soft cataract. This should not deter the examiner from making a thorough test with the ophthalmometer in every case of aphakia.

The retinoscope is as valuable an instrument in this form of ametropia as any other, and an approximately accurate estimation of the refractive error can easily be made by this method, which has been fully described in previous chapters.

After the amount of the refractive error has been determined, the patient must be seated at the trial-case and the objective test made, as in other forms of ametropia. If the pupillary area is clear and the fundus and cornea free from disease or opacity, the distance vision should be brought to an acuity ranging from 20/40 to 20/20. High degrees of astigmatism tend to grow rapidly less in amount; the vision gradually becomes better each month.

Convex spheres must be added to the distance correction for near use. A +3.00, +3.50, or +4.00 sph., added to the distance correction, usually gives best vision for near. The range of near vision is very slight.

After cataract extraction glasses should not be ordered for six or eight weeks, and even at that time a generous reduction in the astigmatic correction should be made. The test made six months after extraction will usually be found to be quite permanent.

Anisometropia.—This term is applied to cases which occur not infrequently when the two eyes vary in their refractive error. The refractive error in both eyes is, however, of the same kind. The variation may be slight or extreme. The defect

is almost always congenital, but may be acquired, as in cases having the lens extracted from one eye only.

Heterometropia means that the refractive error in the two eyes is different in character—this is, one eye myopic, the other eye hypermetropic.

Both the above conditions may be met with in three chief forms:

(1) Cases maintaining binocular vision.

(2) Cases using the eyes alternately.

(3) Cases in which one eye, that of the greatest error, is permanently excluded from vision and has become amblyopic.

In the first class the variation of the refractive error is usually not very great. If corrected properly, the images on the two retinæ may be equally distinct, or in cases of greater variation the image may be clear in the better eye and indistinct in the other.

When the eyes are alternately used, there is frequently a coincident alternating strabismus. Many of these cases have a true absence of the binocular center, and, a consequence, never complain of diplopia. In this class are also cases having myopia in one eye, which is used for near vision.

When one eye is excluded by suppression of the retinal image, the patient frequently manifests a squint. This may be either convergent or divergent, depending largely on the character of the refractive error. Many cases, however, in which one eye is amblyopic do not squint.

Refraction.—Cases in which binocular vision is present or those in which the eyes are alternately used should have their refraction carefully estimated and the proper correction used constantly. The younger the patient, the better this full correction will be borne. The patient manifesting a wide variation will be frequently unable to wear the correcting lens for the eye in which the greater ametropia is found. In squint cases, however, this correcting lens is better borne than in patients manifesting parallelism, and also has a corrective tendency in recent cases of squint.

The physician must be guided by the individual characteristics of each case in prescribing glasses. In many cases the patient will be more comfortable if a plane glass only is placed before the amblyopic eye. This is especially true of those cases in which one eye has been amblyopic from infancy, and which cannot be trained to be useful, in the sense that the other eye is useful. The earlier in life the patient is seen, the better will be the result from correcting the refractive error of both eyes. Certain cases over thirty years of age having an amblyopia ex anopsia in one eye, may, with training and proper lenses, regain useful vision. (See Case 14, Chapter XV.)

CHAPTER XII

REFRACTION IN RELATION TO MUSCLE IMBALANCE

The eyes are controlled by a delicate system of muscles which, acting simultaneously in both orbits, keep the eyes in coördination. This coördination in normal individuals is so perfect that when the eyes are directed toward an object, the visual axes correspond, and the image of the objects falls on corresponding points on the two retinæ. This condition is called muscle balance, or *orthophoria*. It can be given as a general rule that all people whose eyes are in a condition of orthophoria have binocular single vision. The impression of the retinal images transmitted to the brain is fused at the so-called fusion center, and perceived as a stereoscopic picture. In perfect muscle balance both visual axes will continue to be accurately directed toward an object, even though one eye is screened.

Heterophoria is the condition in which the eyes are not in perfect coördination or balance. The tendency is toward deviation from the visual axis. Because binocular vision exists, this tendency is usually not evident until one eye is covered, when the effort in maintaining binocular vision is unnecessary and the deviation becomes recognizable.

Diplopia, or double vision, is a condition noticed by the patient when one eye alone fixes an object, and the other eye receives the image of the object on a part of its retina not corresponding to the fixing eye. Under these conditions the object is not fused and the brain perceives the object as double. The image of an object formed on the retina outside the fovea is projected in the opposite direction, *i. e.*, images formed above the horizontal meridian are projected downward, and images formed on the nasal side of the retina are projected toward the temporal side.

Homonymous Diplopia (Fig. 88).—This is a condition in which the false object is seen on the side corresponding to the deviating eye. In Fig. 88 the left eye (O. S.) is fixing the object O, but the right eye (O. D.) is convergent, and the image of O falls to the nasal side of the fovea, which, in consequence, is projected to the temporal side at F. Homonymous diplopia is artificially produced in esophoria and in convergent strabismus.

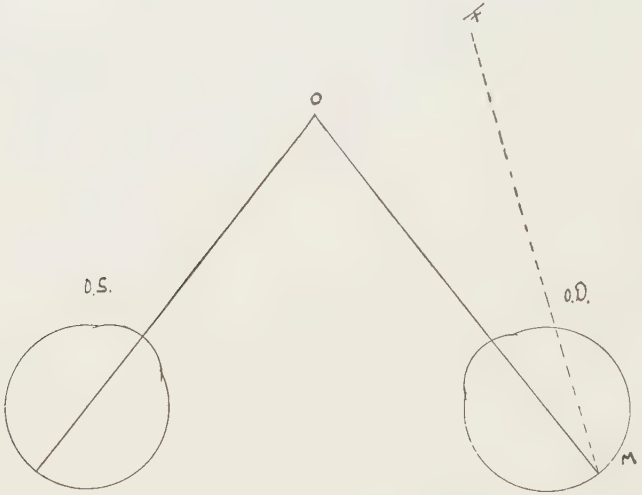


Fig. 88.—Homonymous diplopia.

Heteronymous Diplopia; Crossed Diplopia (Fig. 89).—In this condition of muscular imbalance the false object is seen on the side opposite the deviating eye. In Fig. 89 the left eye (O. S.) is fixing the object O, but the right eye (O. D.) is divergent and the image of O falls on the temporal side of the retina, which, in consequence, is projected to the nasal side at F. Crossed diplopia is produced in exophoria and divergent strabismus.

Muscle imbalance is divided into two main classes—strabismus and insufficiency. Strabismus is considered in the following chapter.

Muscle insufficiency is divided into many varieties, depending

upon the character and direction of the deviation. The almost endless classification given by most authors seems unnecessary and is of little value, except in the minds of the originators, who believe all the ills of the flesh are due to muscle errors. The pity is that these "muscle-maniacs" convince most of their patients that the above statement is true, and have succeeded in producing a class of patients—"muscle-neurasthenics"—who are no comfort to themselves or others. Happily, more conservatism is now shown in regard to muscle imbalance and the indiscriminate use of prisms, and the greater evils, tenotomies and partial tenotomies, have sunk to their true position of

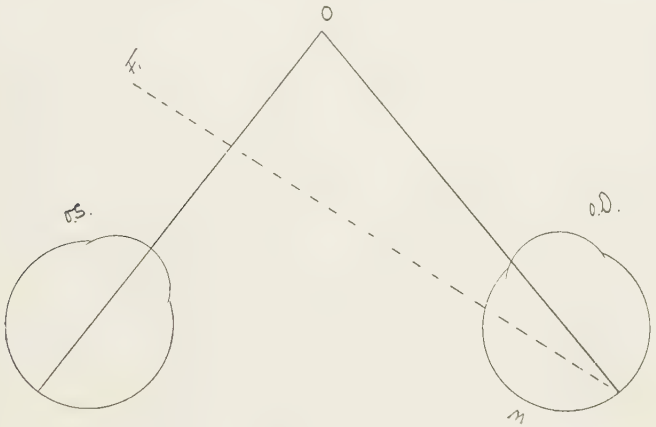


Fig. 89.—Heteronymous diplopia.

importance. It is not to be inferred that prisms or tenotomies, partial or complete, are never indicated, only that too much importance has been given to muscle errors. Muscle-cutting and prisms have been resorted to in cases of muscle imbalance which could have been permanently relieved without either of these means, by seeking and removing the cause.

Classification.—For the sake of simplicity, a reasonable classification is given below:

Esophoria is a tendency for the visual axes to deviate inwardly.

Exophoria is a tendency toward outward deviation of the visual axes.

Hyperphoria is a tendency toward upward deviation of the eye.

Cyclophoria is a tendency to abnormal rotation of one or both eyes around the anteroposterior axis.

Etiology.—Undoubtedly, the chief cause of muscular insufficiency is ametropia. The cause may also lie in anatomic defects of one or more of the ocular muscles. Serious illness may make manifest a muscle insufficiency. Disease of the nose or its accessory sinuses is one of the chief causes of muscle insufficiency, and the reëstablishment of muscular equilibrium lies in the treatment and relief of the nasal cause rather than in treatment applied to the muscles themselves. Within the past five years various observers have shown the close relation between accessory sinus disease and muscle imbalance.

Symptoms.—Symptoms due to muscle imbalance alone are rarely found, unless the degree of imbalance is so great that the muscles relax and diplopia is produced. Patients manifesting a muscular insufficiency complain of all the various asthenopic symptoms, but these symptoms are due more to the ametropia than to the imbalance itself. Given an emmetropic eye with muscular insufficiency, which is rare, the patient will rarely seek the services of an ophthalmologist because of asthenopic symptoms. Rarely a patient will have a consciousness that one eye turns out or in, and this is accompanied by dizziness and perhaps nausea. Such definite symptoms pointing to muscular trouble are far from common. The usual histories are similar to those described under symptoms of the various errors of refraction. If, however, the patient complains of the symptoms of eye-strain, and the refractive condition of the eyes is emmetropic, or has been made so by proper correcting lenses, the muscular insufficiency will be at fault and will need suitable treatment.

Diagnosis.—The mobility of the eyes should be tested before the regular tests for muscle imbalance are made. This is easily determined by seating the patient directly in front of the examiner. The patient is instructed to keep his head perfectly

still, and follow with his eyes the tip of the examiner's finger, which is moved in all directions about 15 inches before the patient's eyes. In this manner a defective power of motion in any direction is easily noticed.

To determine roughly the power of the internal recti, a pencil is held about two feet directly in front of the patient, and he is instructed to fix his gaze on the tip. The pencil is approached slowly until within an inch or two of the nose. If there is any weakness of one or both interni, the eye with the weaker muscle will be unable to fix when the pencil is near the nose and will deviate outward.

Tests for Muscle Imbalance at 6 Meters.—Tests for muscle imbalance both for distance and near should be made

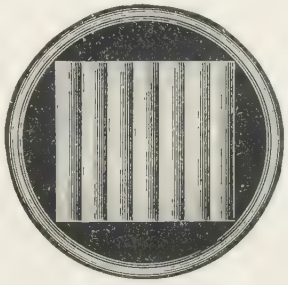


Fig. 90.—Maddox multiple rod.

only when the patient is wearing the full correction of his ametropia. There are three tests at 6 meters which are of value, and each has points of advantage. These are the Maddox rod, the cover, and the diplopia tests.

The Maddox Rod (Fig. 90).—This is a round, transparent rod, or a series of rods, as shown in the illustration, which act as strong cylinders and refract rays of light in one plane only, which lies at right angles to the rod. A point of light looked at through the rod will appear as a narrow band of light. Behind the rods is placed a plane red glass which increases the contrast. When the multiple rods are used, the central clear broken line is the image to be noticed by the patient.

In using the Maddox rod it is advisable always to place it before the same eye, usually the right, which makes the muscle tests consistent. When the patient looks at the bright point of light 6 meters away, with the rod before the right eye and the left uncovered, the point of light will be seen as a point with the left eye and as a red streak with the right eye. To test the lateral deviation, the Maddox rod is placed in the trial-frame with the rods horizontal. If orthophoria is present, the vertical red streak will run through the bright point. This shows fusion. If the red line is seen on the right of the light, the rod being in front of the right eye, the diplopia is homonymous and the condition is that of esophoria. If the red line is on the left of the light, the rod being in front of the right eye, the diplopia is heteronymous, and the condition is that of exophoria.

It will be noticed by the examiner that, in many cases, when the lateral deviation is measured with the Maddox rod, the patient will say that he can make the line run through the light after he has looked at the light for some time. He is in this case overcoming the tendency of one eye to deviate from the visual axis of the other, and the test, as a consequence, is of but slight value in lateral deviations.

In vertical deviations, however, the Maddox rod test gives the true amount of the muscle insufficiency, for the attempt to fuse the images by the patient is rarely possible in hyperphoria. To test the vertical deviations the Maddox rod is placed before the right eye with the rods vertical. The image of the right eye will then be a red horizontal line. If this line runs through the light, there is orthophoria in the vertical axis; if the red line is below the light, the rod being placed before the right eye, the condition is that of *right* hyperphoria; if red line is above the light, the rod being before the right eye, the condition is that of *left* hyperphoria.

The cover-test for lateral deviation is far superior to the Maddox rod, for in the cover-test one eye is covered and there is no tendency on the part of the patient to maintain binocular vision. The test is made by having the patient look at a bright

point of light, as in the rod-test. The examiner puts himself in such a position that he can observe any movement of the patient's eyes when first one and then the other is covered. The patient should be instructed to keep his gaze fixed on the light, and if the examiner can detect no movement of the eyes when the screen is moved from one eye to the other, there is orthophoria. If the movement of the eye *behind* the screen is inward, the condition is that of exophoria; if the movement of the eye behind the screen is outward, the condition is that of esophoria; if the movement of the eye behind the screen is upward, the screen being held before the right eye, the condition is that of right hyperphoria; if the movement of the right eye behind the screen is downward, the condition is that of left hyperphoria.

The diplopia test is similar to the Maddox rod test, and has no special advantage over the rod-test for 6 meters. Its great value lies in testing the muscular insufficiency for reading distance. The patient is placed at the trial-case as for the previous tests, and in testing for the lateral deviation a 3-degree prism, base down, is placed before the right eye, the left being uncovered. The false image of the light will be above the light, seen in its true position by the right eye. If the false image is directly above the light, there is orthophoria, or muscle balance; if the false image is above and to the right, there is esophoria; if to the left, there is exophoria. In testing the vertical deviation an 8- or 10-degree prism is placed, *base in*, before the right eye. If the right-hand image,—the false one,—is seen below the horizontal the condition is that of right hyperphoria; if above the horizontal, the condition is left hyperphoria.

Tests for Muscular Insufficiency at Reading Distance.—*The line-and-dot test* is made by having the patient look at a black dot with a black line about 3 inches long running vertically through it (Fig. 91). The card on which the line-and-dot are drawn is held about 13 inches in front of the patient's eyes. A 6-degree prism is placed, base down, before the right eye, and if the patient sees two dots, one exactly above the other on one line, there is orthophoria for near. If two lines and two

dots are seen, and the upper dot is on the right, there is esophoria for near; if the upper dot is on the left, there is exophoria for near.

If the line-and-dot are now held so that the line runs horizontally, and the double prism (Fig. 92) is placed before the right eye, three lines and three dots will be seen (Fig. 93). If

Fig. 91.—The line-and-dot test.

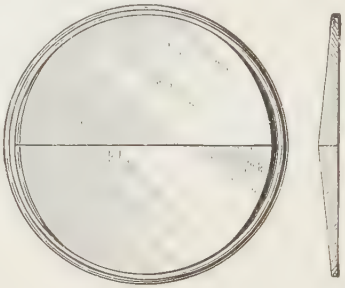


Fig. 92.—The double prism.

the lines are equally separated and the dots are placed in an exactly vertical line, there is no hyperphoria, exophoria, or esophoria for near. There is also no cyclophoria if the middle line is parallel to the other two. If the middle line lies nearer the upper false image, there is right hyperphoria; if nearer the lower false line, there is left hyperphoria. Lateral deviations

Fig. 93.—Image produced by double prism of line-and-dot test held horizontally.

are best tested with the line vertical, as previously described. If the three lines are not parallel, there is cyclophoria. If the middle line,—the true image,—when the double prism is placed over the right eye, appears to dip down to the left, this shows the vertical meridians of the eyes are leaning in the opposite direction toward each other, and the condition is minus cyclophoria

(Fig. 94). If the middle line dips to the right, the condition is plus cyclophoria (Fig. 95).

Estimation of the Amount of Heterophoria. —*Esophoria* is best determined by the cover-test for 6 meters, and the line-and-dot test for near. The strength of the prism, base out, necessary to stop all outward movement of the eye behind the screen in the cover-test, measures the amount of the esophoria for distance. The strength of the prism, base out, necessary to

Fig. 94.—Minus cyclophoria. Double prism test.

bring the two dots directly over one another in the line-and-dot test, measures the amount of esophoria for near.

Exophoria is tested for, and the amount determined in the manner just described for esophoria, except that the prism is placed before one eye, base in.

Hyperphoria is best tested by the Maddox rod for 6 meters. The strength of the prism placed, base down, before the hyperphoric eye which causes the red line to run through the light corrects the hyperphoria for distance. The strength of the

Fig. 95.—Plus cyclophoria. Double prism test.

prism, base down, before the hyperphoric eye which places the middle line half-way between the two false lines in the double prism test corrects the hyperphoria for near.

The rotary prism (Fig. 44) may be placed before one eye for purposes of correcting the degree of muscular insufficiency. This device is rather heavy, but it saves the constant changing of prisms taken from the trial-case. The strength of the prism is varied quickly by means of a screw, and any strength may be obtained from $\frac{1}{2}$ degree up to 30.

Treatment.—The first indication is proper estimation and correction of the refractive error, which in itself is very often sufficient to overcome the muscle error, or at least to relieve the patient from all symptoms. If the insufficiency is still present, and the patient still complains of asthenopic symptoms, the nose and its accessory sinuses should be examined by an expert rhinologist. Ethmoid and sphenoid disease are especially liable to cause muscular trouble, and in these cases it is only through correction of the sinus trouble that the patient may hope for permanent relief. Frontal sinus and antrum disease are less liable to cause muscular trouble than the two sinuses above mentioned, but they should also be thoroughly investigated. Large hypertrophic turbinates and polypi may cause serious asthenopic symptoms, but these symptoms are usually more refractive than muscular. The patient's general health should be carefully looked after, and, if necessary, suitable treatment should be instituted by the family physician.

If the ametropia is fully corrected; if the nose and its accessory sinuses are found normal, and if the general health of the patient excellent, these symptoms of so-called muscular asthenopia are so rare as to be considered a curiosity. In 7000 cases of refraction I have found it necessary to perform a tenotomy for muscle insufficiency but once, and to prescribe prisms for constant use but five times—all six cases had hyperphoria. To prescribe prisms for constant use, and, worse, to operate upon a muscle for muscle insufficiency without having exhausted every means of relief, is exceedingly bad practice. We hear too often from those unfortunates who have "gone the rounds" that first this muscle and then that was cut, until the patient became worse than originally, if for no other reason than the reiterated mental effect. After operation the real cause, unsought for by many ophthalmologists, may right itself, and the patient becomes more uncomfortable than before.

The constant use of prisms, except in some vertical errors, is almost invariably followed by more harm than good; the

symptoms become accentuated and almost always the muscle error becomes greater.

Internally strychnin or, better, tincture of nux vomica, iron, and iodid of potassium, are frequently of great benefit. In other cases bromids are indicated. The eyes should be used carefully, and always under the best conditions.

Prism exercises are of benefit in certain cases of exophoria not due to other causes than a true weakness of the interni. The patient, with his ametropia corrected, is told to stand about two feet in front of and facing a bright light or round black dot on a white background, and to look steadily at the single point. A weak pair of prisms, bases out, are then placed before the eye, and the patient told to walk backward, keeping his gaze fixed on the object. If diplopia develops before he has walked back the length of the physician's office, the patient must raise the prisms and repeat the performance until diplopia does not develop. If diplopia does not develop with the weak prisms, the strength is increased. This exercise may be repeated frequently until the amount of the exophoria is decreased and the patient made comfortable. The internal recti can frequently be strengthened materially in this way. After the exercise has been performed a number of times under the guidance of the physician, the patient may be given a pair of strong prisms to be worn over his ametropic correction when exercising the muscles, which may be done in his own home. A simple exercise for near is to have the patient hold a pencil at a distance of two feet or more from his eyes, and gradually draw the pencil toward his nose until diplopia is produced. When diplopia develops, the pencil is again held at arm's length and the exercise repeated. This exercise is simple and can be easily and often practised by the patient.

Esophoria for distance is usually found in hypermetropic individuals, and occasionally causes severe symptoms of asthenopia. These symptoms are usually entirely relieved by wearing the strongest possible hypermetropic correction constantly.

Hyperphoria of considerable amount (*i. e.*, over 3 or 4 △ degrees) occasionally requires the prescribing of prisms for constant use, or, more rarely, a tenotomy may be indicated. Either of the above procedures should not be resorted to until all other means of correcting the muscle insufficiency have failed, and all possible causes for such imbalance removed.

Cyclophoria is frequently associated with a high degree of oblique astigmatism. The proper correction of this refractive error usually relieves all symptoms, but if the symptoms produced by the cyclophoria persist or are increased after the correction of the ametropia, a slight change in the axes of the cylinders may be of great benefit, without sacrificing much, if any, visual acuity.

CHAPTER XIII

REFRACTION IN RELATION TO STRABISMUS

Strabismus (**Cross-eye; Squint**).—This is a condition of the eyes in which the visual axis of one eye deviates from the point of fixation. The eye, the visual axis of which is directed toward the object, is called the fixing eye; the other, the visual axis of which deviates from the point of fixation, is called the squinting eye. Cases of strabismus do not have binocular vision, because the images of the object on the retinæ do not fall on corresponding portions. Diplopia is almost unknown in squint cases, because the squinting eye has learned to suppress the image on its retina, and from disuse of the retinal function the squinting eye gradually becomes amblyopic. The amblyopia ex anopsia (blindness from disuse) is a result of squint, not a cause, as has been claimed so many years. True cases of congenital amblyopia are exceedingly uncommon, and while amblyopia in one eye may cause a quint, such eyes more frequently do not squint.

Worth has pointed out that a squint is caused in large part by an absence or a defect in the fusion center, which, combined with a higher degree of ametropia in one eye than the other, and the character of ametropia, determine the variety of the squint. Most squinting eyes have a greater amount of refractive error than the fixing eyes, and because of the amblyopic ex anopsia have a much diminished vision. The amblyopia and the greater ametropia in the squinting eye are much more often found in late than recent cases of squint, and for this reason the ametropia should be corrected and fusion training begun as early as possible after the squint becomes manifest, in order that binocular vision may be obtained, and equal vision maintained in both eyes.

The old custom of allowing the patient to wait until he has outgrown his squint is bad practice. It is true that many patients, children especially, do outgrow their squint, but they do so at the sacrifice of good vision in the squinting eye. After a certain age it is extremely difficult to reëstablish the function of an amblyopic eye, and more difficult to train the fusion center so that binocular vision is possible.

Varieties of strabismus are convergent, divergent, alternating, vertical, periodic, concomitant, and paralytic.

Convergent Strabismus.—*Etiology.*—The old theory of Donders, who considered that the tendency to abnormal accommodation in hypermetropes caused convergent strabismus, is the most commonly accepted cause. It would be more nearly true if we accepted this theory in connection with that advanced by Worth, who considers that all cases of squint are due to a lack or a defect in the fusion center. This defect causes a lessened or absent binocular impulse, and the most defective eye deviates from the axis of fixation. It must be accepted at true that hypermetropia alone cannot cause squint, but that hypermetropia with defective fusion can and does cause convergent squint.

Symptoms.—In convergent strabismus the visual axis of the squinting eye is deviated inward, so that the visual axis of the squinting eye and the visual axis of the fixing eye cross each other (Fig. 87). The diplopia, which may be artificially produced in these cases, is homonymous. The refractive error is almost always hypermetropia, and the squinting eye will usually show a higher degree of ametropia than the fixing eye. This variation is not often found in early cases of squint.

Most cases of convergent squint begin in early childhood, and it is at this time that the cases should be carefully refracted and fusion training begun. The mother will usually state that the child's eyes turned in after an attack of measles, whooping-cough, or some one of the various children's diseases. Whatever may have been the immediate cause, the real cause has been

given under etiology, and the indication is for immediate treatment.

Treatment.—The amount of the squint can be determined in two ways: one by the cover-test, as described in the previous chapter, and the other by means of the perimeter. The perimeter test is made by having the patient sit with his chin on the rest, provided for this purpose with the squinting eye opposite the center of the arc, which is placed horizontally. The patient is then instructed to gaze at some distant object beyond

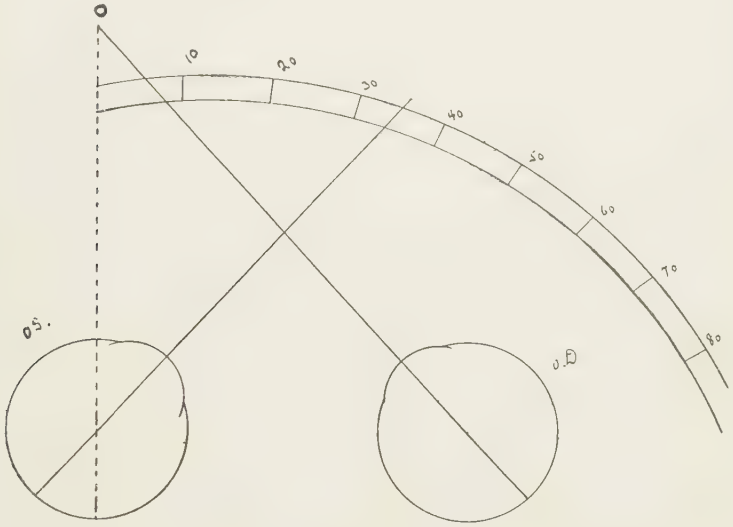


Fig. 96.—Testing degree of squint by means of perimeter.

the center of the perimeter, while the examiner carries a lighted candle around inside the arc. When the reflection of the candle-flame is seen to correspond to the center of the cornea of the squinting eye, the amount of deviation is determined by reading off the number of the arc at the position of the candle (Fig. 96). An estimation of the character of the refraction is determined by retinoscopy, and the patient given a $\frac{1}{2}$ per cent. solution of atropin, to be used three times a day for from three to six days.

When the patient returns for the cycloplegic examination,

the refraction is determined as previously described, and the amount of the deviation again determined, with the patient wearing his full ametropic correction. The deviation at the cycloplegic visit will usually be much less than at the preliminary visit, and often parallelism will be noticed.

A suitable reduction should be made from the full amount of the refractive error, and the glasses ordered for constant use. The eyes will gradually become accustomed to the lenses as the effect of the atropin wears away. The patient should be instructed to report in two weeks for observation. Certain cases will be entirely relieved by the correcting lenses, but most patients need additional training before the retina of the squinting eye will regain its function, and also before binocular vision will be developed.

Worth claims that the fusion faculty is well advanced by the first year, and is complete by the end of the sixth year. According to his teaching, nothing short of actual paralysis will cause convergent squint after the fusion faculty is well developed. Therefore it is with young children, soon after their squint becomes manifest, that we obtain the best results from training, although this should be undertaken in every case.

If the squint is still apparent at the postcycloplegic visit, the patient should be instructed to cover the good eye for several hours each day and allow all work to fall upon the squinting eye. If the child takes unkindly to this method, the fixing eye should be kept for a varying length of time under the influence of atropin. Just enough atropin should be used to keep the ciliary muscle paralyzed. The child will then be compelled to use the squinting eye for near vision, and soon learns to use the eye for distance also. Care must be taken in using atropin that no toxic effects are produced, and also that the previously fixing eye does not become convergent. It is wise to have such patients frequently under observation. If the fixing eye becomes convergent or the eyes become parallel, the treatment should be discontinued, except the constant use of glasses. If the squint is still manifest a month or six weeks after correction of the

ametropia, fusion training should be started. This is best accomplished by means of the amblyoscope, which cannot be used when the eyes are under the influence of a cycloplegic.

The amblyoscope (Fig. 97) is an instrument which consists of approximately two half-tubes joined together by a hinge which allows them to be separated or brought together to suit the angle of the squint. At each end of the tube is a place for object slides, which consist of devices on transparent paper. Each is illuminated by an electric bulb or small lamp, which can be regulated as to the intensity of the light, and also adjustable to

Fig. 97.—The Worth-Black amblyoscope (de Schweinitz).

the angle of the tubes of the amblyoscope (Fig. 98). The intensity of the light is increased or diminished by bringing the lamp nearer or pushing it away. The object slides are of three classes: (1) Those which do not require blending of images, but only simultaneous vision of dissimilar objects with the two eyes (Fig. 99). (2) Those which require true fusion in order to make a perfect picture (Fig. 100). (3) This class consists of devices which can be appreciated only by patients having a high grade of binocular vision, which is true perspective (Fig. 101).

The training should be undertaken as early as possible, under the direction of the physician, before the squinting eye has become amblyopic. The vision of young children can be

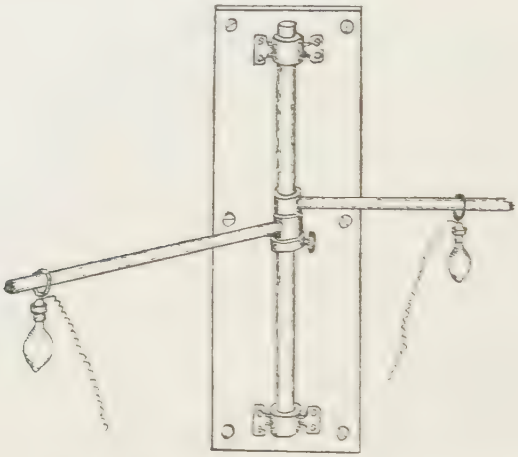


Fig. 98.—Adjustable bracket for illuminating the amblyoscope (Worth).

fairly accurately determined by means of various sized white balls. The balls vary in size from $\frac{1}{4}$ inch to 2 or 3 inches in

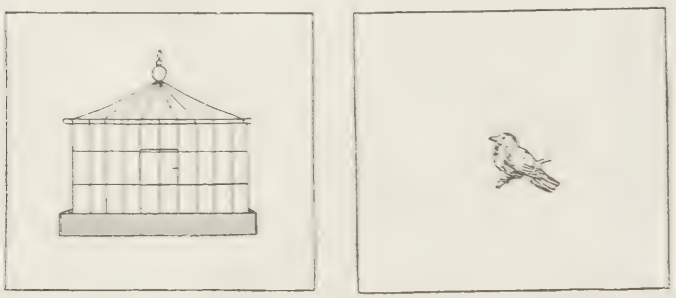


Fig. 99.—"Bird in cage," for simultaneous vision of dissimilar objects (Worth).

diameter. The child will be asked to follow the ball with his eyes as it is rolled away from him. The examiner can quite easily determine when the child loses sight of it by a lack of

concentration on the object. It is almost unnecessary to say that each eye should be tested separately.

The simple stereoscope, arranged so that prisms may be inserted before the lenses, is often of much benefit in fusion training. The stereoscope is an excellent test for the presence

Fig. 100.—Images requiring true fusion when seen through the amblyoscope.

of binocular vision in older patients. Similar pictures to those previously described (Figs. 99 to 101) are used in the stereoscope.

If the constant wearing of the strongest possible correction of the refractive error, the fusion training, and the covering of

Fig. 101.—Images requiring perspective when seen through the amblyoscope.

one eye do not restore parallelism or binocular vision after several months of trial, a suitable tenotomy or advancement, or both, is indicated. The technic of these operations can be found in any text-book on the eye. No operation should be resorted to until all other means of restoring parallelism have been tried. Often the fusion faculty is trained, but parallelism

is not reëstablished, in which case operation is a necessity in order to hold all that has been gained.

Cases that do not respond to fusion training are those having a true altering squint, and have no binocular center, or those having a marked amblyopia. The amblyopia in the latter class of cases could and should have been prevented by appropriate early treatment.

Glasses for constant use are successfully prescribed for children as young as one year of age. It is astonishing how well glasses are borne by young children. Frequently a child will be fussy on arising until his glasses are put on. In order to obtain the best possible results the treatment above should be instituted as soon after the squint has become manifest as possible. By early treatment many children are saved from the necessity of an operation, and are almost invariably saved from having an amblyopic eye.

Divergent Strabismus.—This is a condition in which the visual axis of one eye deviates outward, the other fixing the object. The refractive error is usually myopic, and the diverging eye frequently has a greater amount of ametropia than the fixing eye, and is often amblyopic. Divergent squint is not uncommon in eyes which have become blind through injury or disease.

Treatment.—If the refractive error is myopic, much may be gained by proper correction of the ametropia combined with fusion training, as outlined under convergent squint. This method of restoring parallelism and binocular vision is not so successful as in cases of convergent squint. Parallelism is rarely reëstablished except in the recent cases of divergence. Operative interference is indicated early in these cases, and even when parallelism is reëstablished by operation the result is usually cosmetic only, as the diverging eye rarely regains its function.

Divergent squint is, fortunately, much more uncommon than convergent squint, as it is much less amenable to treatment.

Alternating Strabismus.—In this condition at different

times the right eye squints and the left fixes, or the left eye squints and the right fixes. The vision in both eyes is usually equal, and the refractive error may be emmetropic, myopic, or hypermetropic, and is rarely of high degree. These cases of alternating squint have a true absence of a fusion center and hence never have binocular vision. There is never any fusion, and as these patients look through an amblyoscope or a stereoscope, but half of the picture is seen at one time. The half seen depends upon which eye is being used. These patients almost never complain of diplopia. The suppression is perfect in either eye. The reason amblyopia does not develop is because the eyes are used alternately. Most patients having true alternating squint are able to use either eye at will.

Treatment.—If the refractive error is marked and is consistent with the variety of squint, much may be accomplished by the constant use of proper glasses. If, on the contrary, the refractive error is slight or the eyes are emmetropic, parallelism can be obtained only by operation. Nothing can be gained by fusion training, as these cases never fuse.

Vertical Strabismus.—This is a condition in which the visual axis of one eye is deviated upward or downward.

Treatment.—This form of squint is rarely cured by means of correcting the ametropia. Prisms may be of some value, but operation will usually have to be resorted to. The degree of squint is carefully determined by the perimeter or cover-test, and a tenotomy or advancement performed, as seems necessary. In using the cover-test a better contrast is obtained by placing a red glass before one eye.

Periodic Strabismus.—This condition should be more truly classified under heterophoria, as in these cases the squint is intermittent—the deviation of the visual axis of one eye is only occasional. Periodic squint is, however, usually an early indication of constant squint, and treatment in this stage with proper correcting lenses and fusion training will usually prevent the development of squint. If periodic squint is due to opacities in the media of an eye, little can be accomplished by treatment.

Concomitant strabismus includes all varieties previously described. The condition is one in which the squinting eye moves equally with its fellow, or at least will follow the fixing eye when looking in all directions. The word concomitant is used to distinguish the cases of true strabismus from those due to paralysis.

Paralytic strabismus is the condition in which the squinting eye is restricted in its movement in one or more directions, due to paralysis or paresis of one or more of the extra-ocular muscles.

Paralytic squint due to direct injury should be operated upon at once by suturing the divided muscle. All cases of paralytic squint complain of diplopia, except in total third-nerve paralysis, which also causes ptosis and thus shuts out vision on the affected side.

Correction of the refractive error will have no effect in these cases, and operation is never indicated until all other means of treatment have failed. As most cases of paresis or paralysis of the extra-ocular muscles are due to syphilis, mercury, and especially potassium iodid, should be given to the physiologic limit.

CHAPTER XIV

THE ASTIGMATIC AXIS IN RELATION TO NASAL OBSTRUCTION

In refracting a series of cases the examiner cannot but be impressed with the fact that a certain number of patients respond unsatisfactorily to the astigmatic tests, both subjective and objective. In the preliminary examination the patient will often select as the blackest line on the astigmatic chart one which is many degrees distant from the line later selected at the cycloplegic visit. In other cases the line chosen early in the examination may be entirely different from one chosen fifteen or twenty minutes later.

In such cases it has been the custom to infer that a cycloplegic examination will be the only accurate way of determining the correct axis. It *is* the only way of determining the correct axis for the *day* of the cycloplegic test. At the postcycloplegic visit the cylinder previously determined may not be accepted, or, if accepted, will be taken only in an axis more or less at variance with the so-called true axis, determined by cycloplegic examination.

The cases in which this variation is found usually manifest this condition in but one eye only, the other eye often having been accurately refracted at the preliminary visit, and not subsequently changed by cycloplegic or postcycloplegic tests. In such cases a nasal examination will almost invariably show a nasal obstruction on the side of the nose corresponding to the eye which has been difficult to refract. This obstruction may be due to enlarged turbinates (more often the middle than the lower), spurs, polyps, or a deviation of the septum toward the affected side. The action of this obstruction is of the reflex nervous type, which produces an irregular contraction of the

ciliary muscle on the affected side, thus altering the astigmatic error.

There are few, if any, ophthalmologists who have not had patients whose refractive errors, mostly one sided, have not changed to a marked extent, and, frequently, within a comparatively short time. These cases are easily explained by nasal reflex action. If the examiner prescribes the glass according to the cycloplegic examination in these cases, the patient will almost invariably complain, and complain strenuously. The patient's other alternative is to consult another physician.

Accessory sinus disease is not so powerful a factor in producing variation in refractive errors as cases of nasal obstruction *per se*, but the effect of sinus disease cannot be ignored. The sinus disease in itself may have been caused by nasal obstruction, or, secondarily, may cause nasal obstruction by polyp formation or chronic thickening of the tissues lining the nasal cavity.

The variation of the axis and amount of astigmatism is due to the fact that the nasal condition varies from time to time either from the effect of treatment or even climatic conditions. It has been repeatedly demonstrated in these cases that nasal treatment, nasal operation, or climatic change has brought great relief.

The nasal condition found in these cases is contact; the middle turbinate is usually found pressed hard against the septum. Many other pathologic conditions in the nose produce a similar condition. It can easily be inferred, and has been repeatedly demonstrated in certain cases, that contact (obstruction) may be present one day and absent the next. This variation in the nasal condition causes a variation in the astigmatic axis and, as a consequence, the patient has marked asthenopic symptoms one day and is comfortable the next.

Monocular pain, or unilateral headache, with objective and subjective astigmatic tests, varying or unsatisfactory, should lead the physician to suspect nasal trouble. If the history and preliminary examination lead the examiner to suspect nasal

trouble, the case should be referred to a rhinologist before the refraction is determined.

If nasal obstruction is of sufficient amount to warrant operation, this should be unhesitatingly done in order that the patient may get permanent relief. Local treatment of the nose other than operation is rarely sufficient to cure a patient having asthenopic symptoms due to nasal reflex.

In certain cases a nasal obstruction will cause a more or less permanent astigmatism, which remains in a constant axis. Subsequent nasal operation will change the axis of the astigmatism so that the lens which had corrected the refractive error before operation is no longer suitable. (See Case 25, Chapter XV.)

The amount of ametropia found in these cases is rarely of great amount. An astigmatic error of from 0.5 D. to 1.00 D. is the amount usually found.

Some cases of monocular asthenopia do not show this variation in the astigmatic axis, but do show nasal obstruction, which must be treated before the ocular symptoms are relieved. Correction of the refractive error in these cases, even though this is constant, will only partially relieve the symptoms.

The physician who confines his practice to the eye alone should become familiar with the use of the nasal speculum, and should be able to diagnose nasal and accessory sinus diseases, if only for the purpose of intelligently referring these cases to a rhinologist.

At the present time many rhinologists will not admit an intimate relation between the eye and the nose, and refuse to operate many cases which manifest ocular symptoms only. The ophthalmologist must, therefore, be able to diagnose nasal conditions which might cause reflex symptoms, and thus relieve the patient from the time and expense entailed by consulting a rhinologist unnecessarily.

The study of the far-reaching effects of nasal reflex is as yet in its infancy, and much is to be learned from further study along these lines.

The points in this short chapter are advocated because of the author's firm belief in nasal reflex asthenopia, and also in the belief that these cases are only temporarily relieved until the underlying cause, the nose, has been properly and intelligently treated.

These cases should not be given lenses until the nose has been examined by one familiar with the conditions causing ocular symptoms from nasal disease, and this condition treated if found. If a nasal operation is necessary, refraction should not be attempted until at least two weeks following the operation, because the swelling caused by the operation will in itself cause obstruction. This will usually have subsided within a week or ten days.

CHAPTER XV

CASES

THE following cases are taken from my private records, and serve to illustrate the subject matter in the preceding chapters:

Case I.—Hypermetropia. Catherine B., twenty-five years; stenographer.

November 29, 1902: *History:* Had been wearing +0.25 sph. O. U. for two years. Principal trouble at present is headache after use of eyes. No other symptoms.

Examination: Eyes appear normal.

V. O. D. = 20/20 + 0.87 sph. = 20/15
V. O. S. = 20/20 + 0.75 sph. = 20/15

Muscles: Balance dist. 2 △° exophoria near.

Retinoscopy: +2.00 +2.00

Astigmatic charts: +2.00 sph. before each eye (separately) shows no astigmatism. No mydriatic thought necessary.

Ordered: O. D. + 0.87 sph.
O. S. + 0.75 sph.—*Constant.*

Case II.—Hypermetropia. Harriet C., twenty-nine years; school-teacher.

September 27, 1904: *History:* Patient has worn glasses for eight years. Has no headaches, but eyes easily tire, and letters run together and blur after reading for any length of time. Wearing +2.50 sph. O. U.

Examination: Eyes appear normal.

V. O. D. = 20/40 + 2.75 sph. = 20/20
V. O. S. = 20/40 + 3.00 sph. = 20/20

Muscles: 6 △° esophoria for distance; 2 △° esophoria near. Binocular vision with stereoscope. Oculation, left.

Homatropin and cocain, of each, 1 per cent. One drop to be instilled into each eye to-night and one drop every ten minutes for an hour just before returning to the office for appointment.

September 28, 1904:

V. O. D. = 20/300 + 4.50 sph. = 20/20
V. O. S. = 20/300 + 4 75 sph. = 20/20

Retinoscopy: +5.50 / +5.50 O. U.

Astigmatic charts: O. D. −0.25 cyl. 30°. O. S. −0 12 cyl. 120°. Will accept no cylinder at trial-case

September 30, 1904: Postcycloplegic visit.

V. O. D. = 20/40 + 3.50 sph. = 20/20
V. O. S. = 20/40 + 3.75 sph. = 20/20

Muscles: 5 △° esophoria distance.

Ordered constant.

October 4, 1904: Glasses verified. They are accurately centered and are placed perfectly before the eyes.

Case III.—Simple hypermetropic astigmatism. H. L. C., thirty-three years; merchant.

January 20, 1906: *History:* Patient has had severe stomach trouble (dyspepsia) and frontal headaches. Some nausea following headaches which usually occur in the afternoon, but occasionally on arising. The morning headache can usually be attributed to indiscretion in diet.

Examination:

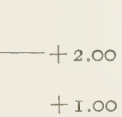
V. O. D. = 20/20 + 1.00 cyl. 75° = 20/20+
V. O. S. = 20/20 + 0.75 cyl. 165° = 20/20+

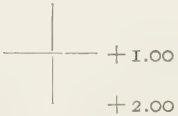
Because of the fact that the astigmatism was with the rule in the right eye and against the rule in the left, it was thought best to have the patient return for cycloplegic test. Retinoscopy verified the results of the subjective test. Homatropin and cocain.

January 22, 1906:

V. O. D. = 20/30 + 1.00 cyl. 75° = 20/20+
V. O. S. = 20/30 + 0.75 cyl. 165° = 20/20+

Charts: − 1.00 cyl. 165°
− 0.75 cyl. 75°

Retinoscopy: 

O. D.


O. S.

Muscles: 2 △° esophoria for distance.
Ordered: O. D. + 1.00 cyl. 75°
O. S. + 0.75 cyl. 165°.—*Constant.*
January 24, 1906: Glasses verified.
February 22, 1906: No headache for nearly a month.

Case IV.—Compound hypermetropic astigmatism. Lelia A., sixteen years; school-girl.

March 23, 1904: *History:* Frequent headaches over and in eyes, after use of eyes especially. Vision poor O. S. Eyes tire easily. General health good. Has never had eyes examined.

V. O. D. = 20/30
V. O. D. = 20/70

Shadow-test shows high hypermetropia with astigmatism.
Muscles: 5 △° esophoria for distance.
Ordered homatropin and cocain, of each, 1 per cent., to be

used every half-hour during next Saturday morning. Appointment, 1.30 P. M.

March 28, 1904:

V. O. D. = 20/200 + 2.50 sph. ⊂ + 1.37 cyl. 95° = 20/20
V. O. S. = 20/400 + 3.50 sph. ⊂ + 2.50 cyl. 105° = 20/50

Astigmatic charts: O. D. − 1.37 cyl. 5°
O. S. − 2.50 cyl. 15°

Fundus: O. S. normal.

Muscles: 5 △° esophoria for distance.

April 5, 1904: Postcycloplegic visit:

V. O. D. = 20/30 + 1.00 sph. ⊂ + 1.00 cyl. 95° = 20/15
V. O. S. = 20/70 + 2.00 sph. ⊂ + 2.00 cyl 105° = 20/40

Would not accept full cylinder in either eye.

Ordered above glass constantly.

April 7, 1904: Glasses verified, but returned to optician because of improper adjustment of frames.

April 8, 1904: Frames properly adjusted.

April 30, 1904: Wears glasses constantly with comfort.

Case V.—Compound hypermetropic astigmatism with presbyopia. Ellen E., fifty-seven years; housewife.

December 11, 1906: *History:* Patient has worn glasses for near use only for about fifteen years. Was given last pair two years ago. Wearing +2.75 sph. O. U. Cannot see to thread needle except in the best of daylight.

Examination:

V. O. D. = 20/40 + 0.50 sph. ⊂ + 0.75 cyl. 180° = 20/20
V. O. S. = 20/40 + 0.75 sph. ⊂ + 0.50 cyl. 180° = 20/20

Astigmatic charts: +2.25 sph. before each eye.

O. D. − 0.75 cyl. 90°
O. S. − 0.50 cyl. 90°

Muscles: Balance.

+3.00 sph. O. U. added to the above distance correction gives the best near vision and the greatest range of accommodation.

Ordered: + 3.50 sph. ⌒ + 0.75 cyl. 180°
+ 3.75 sph. ⌒ + 0.50 cyl. 180°.—*For near use.*

Patient will not accept suggestion to wear distance correction also, even though it is demonstrated to her that the lenses will about double her visual acuity.

December 13, 1906: Glasses verified and properly adjusted. Patient said: "I can see the eye in the needle very well."

Case VI.—Myopia. Sadie K., sixteen years; school-girl.

September 18, 1905: *History:* Given present glasses five years ago, which were the first pair patient had ever worn. No symptoms other than inability to see as well in the distance as formerly.

Wearing −1.50 sph. O. U.

Examination:

V. O. D. = 20/200 − 1.50 sph. = 20/50
V. O. S. = 20/200 − 1.50 sph. = 20/40

Retinoscopy shows increased myopia.

Homatropin and cocain.

September 19, 1905:

V. O. D. = 20/200 − 3.00 sph. = 20/20
V. O. S. = 20/200 − 3.00 sph. = 20/20

Muscles: Balance.

Astigmatic charts: No astigmatism.

Fundi: Normal. No crescents.

September 22, 1905: Postmydriatic visit:

V. O. D. + 3.25 sph. = 20/20
V. O. S. + 3.25 sph. = 20/20

As the weakest minus lens accepted at cycloplegic visit was −3.00 in both eyes, the glasses ordered were −3.00 sph. O. U. constant.

Case VII.—Progressive myopia. Bessie M., thirteen years; school-girl.

October 18, 1906: *History:* Patient had worn glasses for three years, during which time she had consulted two ophthal-

mologists and one optician. One ophthalmologist has prescribed −5.00 sph. O. U. for constant use. He told the guardian of the child that the myopia was much undercorrected, but that it would not be possible to use stronger lenses than those prescribed for one so young. One year ago consulted a second ophthalmologist who prescribed −5.75 sph. ⊂ −0.50 cyl. 180° O. U. Had taken child from school and ordered her in dark-room for greater part of each day. No reading or sewing allowed. Last visit two weeks ago, when physician said glasses were all right, but it might be years before child could use the eyes. Patient now complains of nothing but very poor vision.

Examination:

V. O. D − 5.75 sph. ⊂ − 0.50 cyl. 180° = 20/500
V. O. S. − 5.75 sph. ⊂ − 0.50 cyl. 180° = 20/500

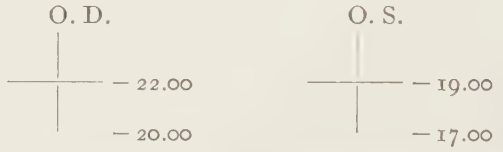
Retinoscopy shows very high myopia.

Atropin, ½ per cent., three times a day for two days.

October 20, 1905:

V. O. D. − 18.00 sph. ⊂ − 2.00 cyl. 90° = 20/70
V. O. S. − 18.00 sph. ⊂ − 2.00 cyl. 90° = 20/70

Retinoscopy:



Ophthalmoscope: Deep choroidal crescents about optic discs. Deep posterior staphylomata. No choroiditis, but there is evidence of some retinal atrophy.

October 28, 1906:

V. O. D. − 19.00 sph. ⊂ − 2.00 cyl. 90° = 20/70
V. O. S. − 18.00 sph. ⊂ − 2.00 cyl. 90° = 20/70

Ordered for constant use. Patient allowed to go to school and study in moderation, always under the best light conditions. Sewing not allowed, and no reading or studying under artificial light.

November 15, 1906: V. O. U. with glasses = 20/50.

Reads easily and likes to do out-of-door things, which have previously been as a closed book. Some plain sewing allowed.

January 10, 1907: Vision same. No symptoms. Patient keeps up in most of the studies of girls her own age.

Case VIII.—Myopic astigmatism. Margaret D., thirty five years; seamstress.

January 23, 1905: *History:* Has been wearing glasses about ten years. Fitted last at Eye and Ear Infirmary. Homatropin test. Wearing −0.75 sph. ⌓ + 1.00 cyl. 90° O. D. −1.50 sph. ⌓ +1.50 cyl. 90° O. S.

Retinoscopy shows a pure myopic astigmatism.

Homatropin and cocain.

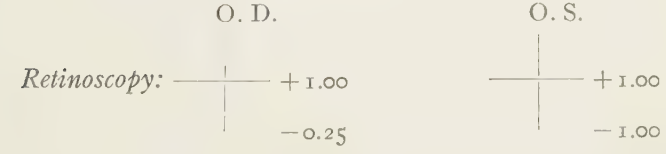
January 24, 1905:

O. D. − 0.25 sph. ⌓ − 1.00 cyl. 5° = 20/20
O. S. − 1.50 cyl. 175° = 20/20

Muscles: Balance.

Charts: O. D. − 1.00 cyl. 5°
O. S. − 1.50 cyl. 175°

Retinoscopy:



January 26, 1905:

V. O. D. = 20/30 − 1.00 cyl. 5° = 20/20
V. O. S. = 20/30 − 1.50 cyl. 175° = 20/20

Ordered above glasses for constant use.

February 3, 1905: Glasses verified. Frames adjusted and centered properly.

Case IX.—Compound myopic astigmatism. J. C. G., twenty-four years; farmer.

October 27, 1902: *History:* Patient has been near-sighted

as long as he can remember. Had never worn glasses until two years ago, when he was fitted by an optician. Wearing—

$$- 5.50 \text{ sph.} \bigcirc - 0.50 \text{ cyl. } 180°$$
$$- 5.50 \text{ sph.} \bigcirc - 1.00 \text{ cyl. } 180°$$

Cannot see well to read with glasses, and in the distance things look small.

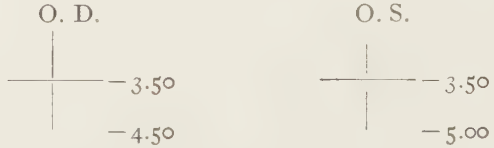
Examination:

V. O. D. = 20/400 − 4.50 sph. ⌒ − 1.00 cyl. 180° = 20/20
V. O. S. = 20/400 − 4.50 sph. ⌒ − 1.50 cyl. 180° = 20/20

Charts: O. D. − 1.00 cyl. 180°
O. S. − 1.50 cyl. 180°

Muscles: 1 △° exophoria for distance; 3 △° exophoria for near.

Retinoscopy:



Ordered: O. D. − 4.50 sph. ⌒ − 1.00 cyl. 180°
O. S. − 4.50 sph. ⌒ − 1.50 cyl. 180°.—*Constant.*

In this case the optician had prescribed lenses in which the concave sphere was too strong and the cylinder not strong enough, the results being that the patient suffered from symptoms similar to those caused by hypermetropia. The underdeveloped ciliary muscle had to accommodate even for distance, and for near more than would be required of a ciliary muscle in an emmetropic eye.

November 15, 1902: By letter: "Read easily, and see things more natural."

Case X.—Mixed astigmatism. Mrs. P. V. B., thirty-two years; housewife.

April 12, 1904: Eyes first tested one year ago by an oculist who used "drops." Has not worn the glasses much because they felt uncomfortable. Wearing +0.50 cyl. 90° O. U.

Subjective and objective tests unsatisfactory, so made homatropin appointment.

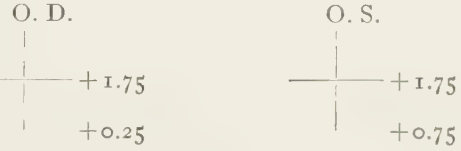
April 15, 1904:

V. O. D. = 20/40 − 0.75 sph. ⌓ + 1.12 cyl. 80° = 20/15
V. O. S. = 20/30 − 0.25 sph. ⌓ + 0.75 cyl. 95° = 20/15

Muscles: 1 △° esophoria.

Charts: O. D. − 1.12 cyl. 170°
O. S. − 0.75 cyl. 5°

Retinoscopy:



April 22, 1904: *Postmydriatic visit:*

V. O. D. = 20/40 − 0.75 sph. ⌓ + 1.00 cyl. 80° = 20/15
V. O. S. = 20/30 − 0.25 sph. ⌓ + 0.75 cyl. 95° = 20/15

Muscles: 1 △° exophoria for near.

Ordered above glasses for constant use.

May 5, 1904: Glasses verified in all particulars. Patient has worn glasses three days with comfort.

Case XI.—Presbyopia. Mrs. Alice C., fifty-two years; housewife.

February 14, 1907: *History:* Patient has been previously fitted to reading glasses five years ago. No trouble except for reading and sewing. Distant vision as good as ever.

Examination:

V. O. D. = 20/20 + 0.50 sph. = 20/20
V. O. S. = 20/20 + 0.50 sph. = 20/20

Muscles: Balance.

Charts: No astigmatism. +2.50 sph. before eyes gives best range of accommodation and most clear vision for near. Had previously worn +1.50 sph. O. U. for near.

Ordered: +2.50 sph. O. U. for near use.

Case XII.—Aphakia following removal of congenital cataract by numerous discissions. Bessie E., fourteen years; student in blind school.

January 10, 1901: *History:* Patient has been nearly blind since infancy. Sees large objects quite well in darkened room or in twilight. Patient has little or no appreciation of colors, no detail. In light room vision is light perception only.

Examination: Atropin dilatation. Central cataract in both eyes; lens clear at extreme periphery. No fundus details made out. V. O. U. with wide pupils = fingers at three inches. No nystagmus. During course of next two years numerous discissions in both eyes resulted in clear pupillary areas, through which details of fundus were plainly seen.

May 8, 1903: Patient wearing as temporary lenses +11.00 sph. O. U. for distance and +16.00 sph. O. U. for near. Complains of headaches and some pain in eyes.

Examination:

V. O. D. = 10/500 + 12.00 sph. ⊂ + 2.00 cyl. 135° = 20/20
V. O. S. = 10/500 + 12.00 sph. ⊂ + 1.00 cyl. 90° = 20/20

Charts: O. D − 2.00 cyl. 45°
O. S. − 1.00 cyl. 180°

Ophthalmometer verifies chart test as to amount and axis of astigmatism.

Fundi: Normal. +12.00 sph. in ophthalmoscope gives good fundus details.

+4.00 sph. added to above lenses gives best vision for near. Snellen 0.5 D. easily read.

Ordered: + 12.00 sph. ⊂ + 2.00 cyl. 135°
+ 12.00 sph. ⊂ + 1.00 cyl. 90°.—*Distance.*

Added +4.00 sph. O. U. for near.

October 15, 1903: Patient goes to school and is not much behind girls of her own age. She rides a wheel easily, and enjoys it. Takes piano lessons, besides her regular school work.

Case XIII.—Aphakia following extraction in capsule of senile cataract. Harry I., fifty-three years; farmer.

December 4, 1907: Simple extraction O. D. in capsule two months ago.

V. O. D. + 8.00 sph. ⌔ + 4.00 cyl. 165° = 20/20

Ophthalmometer: 4.00 D. astigmatism against the rule, axis 165. With +11.00 sph. ⌔ +4.00 cyl. 165° reads Snellen 0.25 D.

Ordered: +8.00 sph. ⌔ +4.00 cyl. 165° distance, and added to above lens +3.00 sph. for near use.

January 15, 1908: By letter learned that the patient's vision for distance and near had remained distinct.

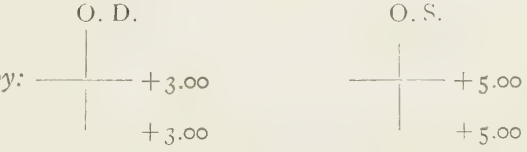
Case XIV.—Hyperphoria; convergence; anisometropia. Edward B., thirty-three years; shoemaker.

May 3, 1901: *History:* Convergence O. S. as long as patient can remember. Has never worn glasses and has never seen well with left eye. Now wishes eye straightened for cosmetic effect. Patient tested with homatropin showed:

V. O. D. + 1.75 sph. = 20/20
V. O. S. + 4.00 sph. = 20/100

Convergence: 40 △° with cover-test.

Retinoscopy:



Charts: No astigmatism.

Ordered: +1.75 sph. O. D. +4.00 sph. O. S.

September 5, 1901: After wearing glasses a few weeks eye became nearly straight and vision has improved O. S. With improved vision diplopia has become quite marked at times.

Muscles: 15 △° convergence. Tenotomy of internal rectus advised and accepted, with result that eyes became parallel.

September 10, 1901: *Muscles:* 4 △° convergence with cover-test. No diplopia except when produced by red glass before O. S.

September 4, 1902: Patient comfortable until four days ago, when diplopia again developed.

Examination:

V. O. D. + 1.75 sph. ⊂ + 0.50 cyl. 75° = 20/20
V. O. S. + 4.00 sph. ⊂ + 1:50 cyl. 120° = 20/30

Note the improvement in vision of the left eye.

Muscles: Left hyperphoria 5 △°. No horizontal heterophoria measurable. Homatropin examination verifies astigmatism as given in subjective test.

Charts: O. D. − 0.50 cyl. 165°
O. S. − 1.50 cyl. 30°
"Fog" test with astigmatic charts.

Patient given potassium iodid in fifteen-drop doses three times a day.

October 11, 1902: Marked increase in diplopia. Noticeable convergence O. S. Good motion in all directions. (Strabismus concomitant.)

Muscles: 15 △° convergence.
4 △° L. hyperphoria.
4° prism base up over right eye and 10 △° base out over left eye gives binocular single vision for distance and near. Increased dose of potassium iodid.

October 17, 1902: *Muscles:* 22 △° convergence for distance, 27 △° base out, divided between the two eyes is required for binocular vision for near. L. Hyperphoria only 1 △°.

Ordered: 9 △° base out, O. U., for temporary use.

October 24, 1902: Convergence 24 △°. No diplopia when wearing prisms. L. hyperphoria ½ △°.

December 5, 1902: Convergence 36 △°. Under cocain advanced external rectus O. S.

January 17, 1903: Convergence 10 △°. Binocular single vision for distance and near without prisms.

This case shows improvement of vision following correction of ametropia in an amblyopic eye. It shows the increase of convergence after use of prisms; also shows the reëstablishment

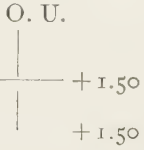
of binocular vision after an uncorrected convergence of over twenty years' standing.

Case XV.—Exophoria. Mrs. W. W. M., thirty-one years; housewife.

July 6, 1905: A year ago patient noticed some diplopia. The condition gradually disappeared, until about a month ago, when diplopia recurred. Has never worn glasses. Has no catarrhal symptoms. *Homatropin and cocain.*

V. O. D. = 20/20 + 0.50 sph. = 20/15
V. O. S. = 20/15 + 0.50 sph. = 20/15

Retinoscopy:



Muscles: 10 △° exophoria; 2 △° R. hyperphoria.

Charts show no astigmatism.

July 8, 1905: V. O. D. = 20/15 + 0.25 sph. = 20/15
V. O. S. = 20/15 + 0.25 sph. = 20/15

Muscles: 10 △° exophoria for distance, 14 △° exophoria for near.

Referred to rhinologist for nasal examination.

Rhinologist's report: Middle turbinate contact left side. Chronic empyema of antrum left side. Operation.

August 10, 1905: *Muscles:* 2 △° exophoria for near. Muscle balance for distance. This case shows marked muscle imbalance and diplopia, caused by nasal and accessory sinus disease. Cured by relieving the cause. Should this case have had the muscles operated upon, and had the nasal trouble later been relieved, imbalance of the opposite kind would have become manifest.

Case XVI.—Strabismus, converging O. D. Ruth A., seven years; school-girl.

September 8, 1904: *History:* Has had transitory convergence of left eye for two or three years, but this convergence has

become constant within the past three weeks. No headaches. No diplopia. Mother had convergence as a child.

V. O. D. = 20/40
V. O. S. = 20/40

Diplopia readily produced by red glass. Cover test shows 12 △° convergence.

Atropin, ½ per cent., for cycloplegic.

September 12, 1904:

V. O. D. = 20/100 + 1.50 sph. = 20/20
V. O. S. = 20/100 + 1.50 sph. = 20/20

Retinoscopy: O. U. +2.75 +2.75

Convergence: 12 △°.

Ordered: +1.00 sph. O. U. for constant use, and mother was instructed to see that the child covered the fixing eye (O. D.) two hours daily. To report in one month.

October 15, 1904: V. O. D. = 20/20 with glass.
V. O. S. = 20/20 with glass.

Has worn cover over O. S. two hours daily for one month.

Muscles: Esophoria, 4 △°. Bar-reading test shows binocular vision, and there are fusion and perspective in looking through the stereoscope.

October 27, 1906: Parallelism with cover-test.

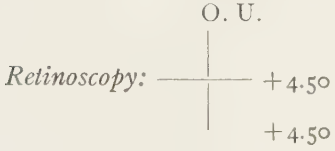
Case XVII.—Strabismus, converging, alternating. Francis K., four years.

April 25, 1903: Uses either eye at will, but oculation is usually left. Convergence for three years. Has never worn glasses.

Atropin examination:

V. O. D. + 3.50 sph. = 20/30
V. O. S. + 3.50 sph. = 20/30

Muscles: Perimeter shows 18° of convergence. No diplopia producible, except with red glass over right eye. No fusion possible. When fusion is nearly accomplished, the homonymous diplopia becomes heteronymous. This is always the case in true alternating strabismus, or is found in any patient who has an absence of the fusion faculty.



Ordered: +2.50 sph. O. U. for constant use.

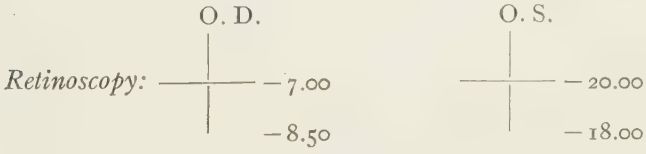
October 29, 1903: Parallelism for distance. Some convergence for near. No binocular vision with stereoscope.

Case XVIII.—Strabismus, diverging O. S. Nellie D., twenty-six years; factory employee.

October 15, 1903: *History:* Patient has never worn glasses and is very near-sighted. Left eye has turned out for several years.

Examination (homatropin):

V. O. D. = F. at 10 feet − 9 sph. ⊂ − 1.50 cyl. 15° = 20/30
V. O. S. = F. at 2 feet − 20 sph. = fingers at 10 feet.



Muscles: Divergence, perimeter test, 15°. Cover-test unsatisfactory, as vision was so poor in O. S.

Ordered: O. D. − 8 sph. ⊂ − 1.50 cyl. 15°
O. S. − 9 sph.—*Constant.*

Patient was told to report in one month, but failed to do so.

This case shows a divergence primarily due to uncorrected myopia. It is possible that had the myopia been corrected in

early life, the amblyopia and divergence would not have developed.

Case XIX.—Conic cornea; irregular astigmatism. Margaret D., twenty-three years; seamstress.

October 30, 1906: *History:* Patient has had poor vision since about five years of age. Was forced to sit in front seat in school in order to see the blackboard. Began sewing for an occupation when eighteen years of age. This work patient has kept up, off and on, until a month ago, when poor vision compelled her to stop work. Has never worn glasses.

Examination: Both corneæ conic. Very irregular cornea seen with Placido's disc.

V. O. D. = 20/400 Stenopeic slit axis 60 = 20/50
V. O. S. = 20/400 " " " 180 = 20/50
V. O. D. pin-hole disc = 20/50
V. O. S. " = 20/50

Ophthalmometer: shows irregular astigmatism, axis 165° O. D., and axis 15° O. S.

V. O. D. = 20/400 + 1 sph. ⌒ + 5.00 cyl. 75° = 20/30
V. O. S. = 20/400 + 1 sph. ⌒ + 5.00 cyl. 105° = 20/30

Above with pin-hole disc before each eye.

V. O. D. with above glass without pin-hole = 20/70 } 20/40
V. O. S. " " " " " = 20/70 }

Ordered: above lenses for constant use.

In this case the axis of the astigmatism was determined by the ophthalmometer and Placido's disc. The amount was determined by subjective test through a pin-hole disc. Retinoscopy and the astigmatic chart test were useless.

This case showed remarkable improvement in vision, and it was with great regret that I lost sight of the patient and therefore was unable to follow the subsequent course of the condition.

Case XX.—Ciliary spasm. Thos. H. C., twenty-seven years; elevator man.

February 2, 1907: *History:* Five weeks ago was rendered unconscious in elevator accident. Wound at side of head above ear. This wound healed by granulation. Has had severe headache since recovery of consciousness, and cannot read. Distant vision blurred.

V. O. D. = 20/40 − 1.25 sph. = 20/30
V. O. S. = 20/40 − 1.50 sph. = 20/30

Muscles: Balance. Atropin, 1 per cent., for use three times a day for four days.

February 6, 1907:

V. O. D. = 20/100 + 1.75 sph. = 20/30
V. O. S. = 20/200 + 1.75 sph. = 20/30

Ophthalmoscope shows slightly hazy retinæ.

Retinoscopy: O. U. +3.00 +3.00

Charts: No astigmatism.

February 16, 1907: V. O. U. = 20/50. Will accept only a −1.50 sph. O. U., which gives 20/30 vision. Range of accommodation limited. Best near vision at 4 inches from eyes.

Ordered: Atropin, ½ per cent., to be used twice a day for two weeks; also ordered +1.25 sph. O. U. for constant use.

March 3, 1907:

V. O. D. = 20/100 + 1.25 sph. = 20/30
V. O. S. = 20/100 + 1.25 sph. = 20/30

Omitted atropin. Patient never returned, and could not get a letter from him, so inferred treatment was sufficient.

This case shows a pseudomyopia and also shows how easy it would be for a beginner to prescribe minus spheres if the subjective test alone was relied upon.

Case XXI.—Swelling of the lens. Second sight, pseudomyopia. Mrs. W. H. De M., sixty-seven years.

January 30, 1908: Vision of left eye has gradually grown worse in past five months. Right eye not so bad. Near vision without glasses has improved.

Examination:

V. O. D. = 20/30 − 0.25 sph. ⌔ − 37 cyl. 90° = 20/30
V. O. S. = 20/100 − 1.75 sph. = 20/20

Charts: O. D. − 37 cyl. 90°
O. S. No astigmatism.

Media: Faint haze at periphery of lens O. D. Quite marked opacity of periphery of lens O. S.

Anterior chamber of left eye narrowed.

Ordered above glass for distance and—

+ 2.50 sph. ⌔ − 37 cyl. 90° O. D.
+ 1.00 sph. O. S. *for near use.*

In this case the patient was told that the glasses would be of but temporary benefit, and that the vision in the left eye would soon become noticeably defective.

This case is one of pseudomyopia due to swelling of the lens, which often occurs in the incipient stage of senile cataract.

Case XXII.—Paralysis of accommodation. Mary D., ten years; school-girl.

December 18, 1905: *History:* Four weeks ago had severe sore throat, which, however, gave negative growth of Klebs-Löffler bacilli. Since recovery, one week ago, has been unable to read, and distant vision is poor. Pupils dilated. Coincident with this, patient had pharyngeal paralysis, with regurgitation of food.

Examination:

V. O. D. = 20/70 + 1.00 sph. = 20/20
V. O. S. = 20/70 + 1.00 sph. = 20/20

Retinoscopy: + 2.50
+ 2.50

Charts: No astigmatism. Lack of accommodation about 2.5 D.

Ordered: +3.25 sph. O. U. for near use as temporary glass.

Tincture of nux vomica and much time to be spent in the open air.

February 22, 1906: Accommodation quite normal.

Ordered: +1.25 sph. O. U. for constant use.

March 15, 1906: Uses glasses with comfort for both distance and near.

This case shows, in a young child, that the correction of the hypermetropia did not permit use of the eyes for near on account of cycloplegia; the patient needed a stronger plus sphere for near until the function of accommodation became reëstablished.

Case XXIII.—Crossed diplopia in a myope, due to ethmoid disease. Mr. E. R., forty-one years; manufacturer.

February 19, 1906: *History:* Patient has worn myopic lenses since he was ten years of age. No trouble until seven years ago, when crossed diplopia developed, and with it marked headaches. Wore prisms without relief. Was given a great quantity of potassium iodid, mercury, and iron. Patient absolutely denies syphilis. Patient spent one year abroad, during which time he consulted several prominent ophthalmologists without relief. A report from one physician under whose care the patient had been for some time shows that the convergence often measured as much as 60 $\triangle^{\circ}$. The latter part of the patient's sojourn abroad he spent in the Swiss Alps, where most of his symptoms disappeared without treatment. He returned to America much encouraged, only to find, after the lapse of several months, that the various symptoms returned. Four years ago his condition was diagnosed as locomotor ataxia. There never, at any time, was any sign of optic atrophy.

During past four years the patient had obtained no relief, but the great fortune for him is that no operation was performed on his ocular muscles.

Examination:

V. O. D. − 16.00 sph. ⌒ − 2.00 cyl. 180° = 20/40
V. O. S. − 15.00 sph. ⌒ − 2.00 cyl. 180° = 20/40

Muscles: 15 △° esophoria. Patient gives history of mouth-breathing for over seven years. Referred to rhinologist.

Rhinologist's report: "Two middle turbinates, as large as lima-beans, removed, and the anterior ethmoid cells curetted under ether."

November 27, 1906—nine months later:

V. O. D. − 19 sph. ⌒ − 2.00 cyl. 180° = 20/40
V. O. S. − 16 sph. ⌒ − 2.00 cyl. 180° = 20/30

Muscle: Balance. Patient has had no diplopia for past eight months. Vision better for distance and near. No headaches.

This case shows a severe case of muscle imbalance and other severe reflex disturbances caused by nasal obstruction and sinus disease. The asthenopic symptoms were relieved only by removal of the cause, which was found in the nose and the ethmoid sinuses.

Case XXIV.—Unilateral headaches from acute frontal sinusitis. Emma S., fifteen years; school-girl.

May 14, 1906: No trouble with vision, either for near or distance. Has had severe headaches over right eye for past week. Worse in morning, and becomes very severe on stooping over. Always has head colds.

Examination: V. O. D. = 20/20
V. O. S. = 20/20

Will accept no lenses.

Muscles: Balance.

Referred to rhinologist, who reports acute frontal sinus empyema on right side. Headache relieved at once by free drainage of sinus. Enlarged middle turbinate on right side blocked opening of infundibulum.

These cases were formerly treated as monocular "neuralgia."

Case XXV.—Variation in astigmatic axis following nasal operation. Dr. A. G. P., twenty-eight years; physician.

October 23, 1907: Patient has been refracted by several prominent ophthalmologists in this country and abroad during past ten years. Last fitted two years ago, by an expert refractionist in this country, who prescribed, after cycloplegic examination, O. D. +0.62 cyl. 130°. O. S. +0.25 cyl. 140°. These lenses relieved all symptoms until one year ago, when patient was operated upon for nasal obstruction on the right side. For past six months glasses have been very unsatisfactory. Nose shows large breathing-space.

Examination (homatropin and cocain):

V. O. D. = 20/40 + 1.00 sph. ⊂ + 0.25 cyl. 35° = 20/15
V. O. S. = 20/30 + 0.62 sph. ⊂ + 0.25 cyl. 105° = 20/15

Retinoscopy: With above lenses before the eyes the retinal illumination O. U. was neutralized with a +1.00 sph.

Charts: O. D. − 0.25 cyl. 125
O. S. − 0.25 cyl. 15

Muscles: 3 △° exophoria for near, balance for distance.

November 22, 1907:

V. O. D. + 0.75 sph. ⊂ + 0.25 cyl. 35° = 20/15
V. O. S. + 0.75 sph. ⊂ + 0.25 cyl. 105° = 20/15

Ordered constant.

The right eye in this case gave the greatest difficulty. The cylinder O. D. given *before* the nasal operation was placed at right angles to the axis found *after* the nasal operation. The relief from intranasal pressure actually changed the axis and amount of astigmatism.

March 16, 1908: No trouble with lenses, headaches, or eye-strain since new lenses were put on.

Case XXVI. Monocular pain and blurring relieved by nasal operation. Mrs. W. H. J., fifty years; housewife.

February 16, 1908: *History:* Left eye had been painful and vision blurred for nearly two years previous to an operation

for the removal of an enlarged and polypoid middle turbinate in the left nostril eight weeks ago. For past five weeks left eye has been as comfortable as the right. Consulted me for bifocal lenses, as she had broken her old ones, which "were no good anyway."

V. O. D. + 3.25 sph. = 20/20
V. O. S. + 2.50 sph. ⌓ + 0.63 cyl. 90° = 20/20

Charts: O. D. no astigmatism.
O. S. − 0.62 cyl. 180°.—*Blur test.*

Muscles: 2 △° esophoria for distance; balance for near.

Ordered above lenses for distance and added 2.25 sph. O. U. for near. Bifocal.

March 4, 1908: Sees well, reads easily, and has no headaches.

In this case I have no record of her ocular condition previous to the nasal operation, but from her symptoms and the examination of similar cases I am sure blurring of the vision of the left eye was due to irregular ciliary spasm caused by nasal irritation.

The causes in this chapter have been as briefly outlined as possible, and all tests not needed, or which showed little or nothing, were not mentioned.

CHAPTER XVI

SPECTACLES, EYE-GLASSES, MEASUREMENTS

Many patients will ask the ophthalmologist if he has any objection to their wearing eye-glasses. The answer to this question depends upon several things. As a general rule, it can be stated that astigmatic corrections, especially if the cylinder is placed "off axis," should be made up in the form of spectacles. These frames are more steady than the eye-glasses, and permit of more accurate adjustment. On the contrary, there are many astigmatic patients who wear eye-glasses with comfort. Their noses are adapted to the various nose-pieces, and the lenses are kept accurately centered and horizontal.

Women object to spectacles more frequently than men, and in these cases I frequently suggest two pairs of glasses, one for every-day use—the spectacles—and one for best—the eye-glasses. When patients insist on eye-glasses, the bar spring is a satisfactory adjustment, as it keeps the lenses perfectly horizontal.

A nose-piece with a small spring spreading horizontally instead of vertically fits many patients perfectly.

When the glasses are simple spherics, plus or minus, eye-glasses may be worn with more comfort than cylindric lenses.

At this point it must again be impressed upon the refractionist that he should see his patients after the optician has filled his prescription. This is necessary not only to be certain that the lenses are properly ground and centered, but that the glasses are properly adjusted to the individual patient.

There are many kinds of *bifocal* lenses; the most common form is the cement bifocal (Fig. 102). This lens is made by cementing the addition made for near use to the distance

correction. The segment is easily removed, if necessary, and a stronger one cemented in its place. For this reason the cement bifocals are the cheapest. The segment may be any shape; the most common shape is shown in Fig. 102, but a very satisfactory shape is seen in Fig. 103.

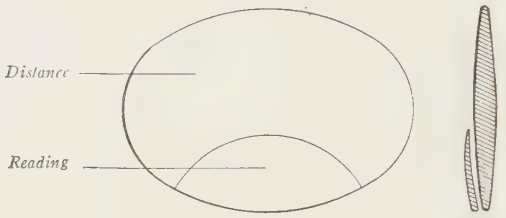


Fig. 102.—Bifocal lens (Pyle).

Acromatic, or *invisible, bifocals* are usually made of two pieces of crown-glass hollowed out to permit the insertion of a biconvex segment of flint glass (Fig. 104); the increased strength is obtained by the greater refractive power of the flint glass. Many patients wear these lenses with comfort and are greatly pleased with the "invisible" effect. Others cannot wear the invisible bifocals at all. It requires careful calculation

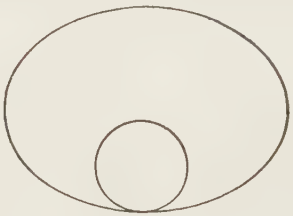


Fig. 103.—Bifocal lens.

on the part of the optician as to how strong to make the segment of flint glass to give the proper effect. Opticians are more expert in making these lenses than formerly. These lenses are high priced, and are objected to on that ground by many patients.

If a patient has to wear lenses for near use only, a very satisfactory lens is the half-lens, which is cut off above and

allows unobstructed distant vision. Many patients are annoyed by the necessity of bending the head away down in order to see over their near glasses when they wish to look away from the work. The half-lens obviates this difficulty.

Some presbyopic patients who need distance as well as near lenses cannot wear bifocals. In these cases it is necessary to have two pairs of lenses constantly with them. If the patient wears spectacles for constant use, the near lenses may be made in "hook fronts," which contain simply the amount of the addition for near and are easily hooked over the correction for distance.

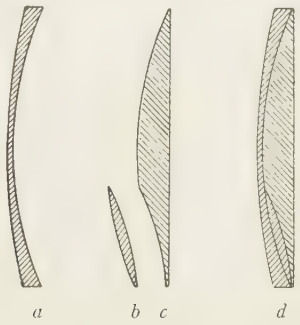


Fig. 104.—Borsch's bifocal lenses (de Schweinitz): *a*, Blade; *b*, disc; *c*, countersunk blade; *d*, completed lens.

Lorgnettes are frequently carried by women, and they are made use of in various ways. They may be fitted with the near correction for temporary use in shopping, etc., or in myopic women, who wear no distance correction, occasionally to improve distant vision.

In monocular aphakia, where the other eye is blind or nearly so, the distance and near correction may be made up in one pair of spectacles which have a reversible nose-piece and straight temples. The near correction is placed before the defective eye when the distance vision is needed, and reversed when near vision is required.

Toric lenses are concavoconvex, the concave surface being placed toward the eye. The lens is ground so that it has on one

surface the optic effects of a spherocylindric lens, or two cylinders of different strengths at right angles to each other. A simple meniscus lens is one which is concave toward the eye and convex away from the eye. It is ground so the difference between the surfaces equals the correction called for. These lenses enlarge the field of vision materially, and are extremely satisfactory in astigmatic cases. The toric lens is quite expensive.

The material for nose-pieces and spectacle-frames should be preferably gold—12 karat or 14 karat. This is the most satisfactory metal and in the end more economical.

Cases having photophobia or whose eyes are under the influence of a cycloplegic should wear "smoked" or amber lenses. Amber lenses are very satisfactory in the majority of instances, and look much better than the smoked.

Decentering Lenses.—This is done for prismatic effect, instead of prescribing a lens and a prism. The rule for decentering is: For every centimeter of decentering there will result as many prism-diopters as there are diopters in the meridian of the correcting lens. Example:

+3 sph. ⌓ 3△ base out is written: +3 sph. decentered 1 cm. outward.

Lenses.—If the examiner is not located near a competent optician, he must order the lenses from elsewhere, and is forced to make his own measurements. Lenses come in various sizes and shapes. They are spoken of as O, double O, triple O, etc. Sizes smaller than O are numbered 1, 2, 3, etc. Different shapes and sizes are lettered. The usual way to designate size and shape is in millimeters, length and breadth, as: 40 × 28 mm., 36 × 26 mm., etc. A guide is furnished by any good optical house, and the lens measurements are easily made. The lenses ordered should conform to the patient's facial measurements.

Eye-glass frames consist of spring and nose-piece. The latter is also called the guard.

Spectacle-frames consist of a nose-piece, often called the bridge, and temples, which extend over the ears. These are

attached to the lenses by means of screws drilled through them in frameless spectacles, and in framed spectacles the temples and nose-piece are attached to the rims.

Measurements Interpupillary Distance.—This measurement is most important, and is made with a millimeter rule. It is difficult to measure from the center of one pupil to the center of the other, and so the measurement is taken from the temporal border of one pupil to the nasal border of the other. The measurement for distance lenses should be made when the patient is looking in the distance, and the measurement for near lens should be made when the patient is looking at a distance of 13 inches. If the lenses are for constant use, an interpupillary distance lying between the two should be ordered.

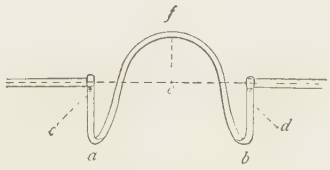


Fig. 105.—Saddle bridge ("American Text-book of Diseases of Eye, Ear, Nose, and Throat").

The bridge should be measured so as to conform to the patient's nose. The usual spectacle-bridge is called the saddle-bridge. The bridge is intended to remain in one place, and the adjustment is made in the arms, not in the bridge. The length of the arms controls the distance of the lenses from the eyes. To raise or lower the lenses the arms are bent up or down. Measurements for the bridge are obtained by means of a soft wire—preferably lead-wire. The wire is molded to the bridge of the patient's nose, and the arms (*c*, *d*) are bent to the proper angle and again bent to show the place of the lenses (Fig. 105). The eyelashes must not touch the plane of the lenses. The width of the base is easily determined with a ruler and the height of the bridge is spoken of as "out" or "in." The height is "out" when *f* extends beyond the plane, and "in" when *f* is behind the plane of the lenses.

A simple way of measurement is by means of various frames used only for purposes of measurement. These will usually be supplied by any optical house.

Length of temples is the measurement taken from the top of the ear to the plane of the lenses.

The size of the lenses, as previously stated, depends upon the facial measurements of the patient, and is usually recorded in millimeter measurements.

If glasses are to be worn constantly, they are made up in distance frames, in which the lenses are placed vertically or inclined very slightly downward. Near lenses are made up in near frames, in which the lenses are inclined quite a little downward.

Measurements for eye-glasses are very similar to those made for spectacles. The principal measurements are for the nose-

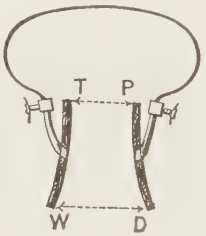


Fig. 106.—Nose piece and measurements (Thorington).

piece, or guard, and the arms which hold the lenses. The average length of the guard is about 14 mm., and the distance between the upper and lower points, where they will press the nose, is best measured by sample frames used for this purpose. The length of the guard and the length of the arm must be carefully obtained. It is also necessary to measure the position of the guards relative to the plane of the lenses (Fig. 106).

The measurement for bifocals is simple. After the size of the lens is determined, the segment measurement should be made so that the upper portion will not quite extend to the center of the distance lens.

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